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MINISTRY OF AGRICULTURE.

IRRIGATION IN EGYPT.

BY

J. BAROIS,

Engineer-in-Chief des Ponts et Chaussées,

PRINCIPAL SECRETARY TO THE MINISTRY OF PUBLIC WORKS IN EGYPT.

PARIS, 1887.

Translated from the French

BY

MAJOR A. M. MILLER,

Corps of Engineers, U. S. Army, 1888.

WASHINGTON:

GOVERNMENT PRINTING OFFICE,

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UNITED STATES ENGINEER OFFICE,

St. Louis, Mo., October 16, 1888.

SIR: I have translated from the French a report on irrigation in Egypt by M. J. Barois, principal secretary to the ministry of public works in Egypt. The translation, with the plates, is forwarded by this mail.

I have thought that it would be considered worthy of publication, as at this time the subject of irrigation is receiving considerable attention in this country and an appropriation has been made by Congress for preliminary surveys and investigation of the subject.

The translation is also interesting as giving recent facts in regard to the regimen of the Nile and some of the methods employed for protection of the banks on that river.

Very respectfully, your obedient servant,

A. M. MILLER,
Major, Corps of Engineers.

The CHIEF OF ENGINEERS, U. S. ARMY,
Washington, D. C.

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IRRIGATION IN EGYPT.

INTRODUCTION.

Up to the present day we have no other data concerning the methods employed by the ancient Egyptians in the art of irrigation than the general and quite vague information which has been handed down by the Greek and Roman authors. The soil and monuments of Egypt, examined with so much ardor by the learned since the beginning of the present century, have revealed nothing, or almost nothing, on this subject.

Although we find in many parts of Egypt gigantic pyramids, the ruins of imposing temples, and vast cemeteries dating from the most remote epochs of history, it is remarkable that we have discovered only very faint traces of Pharaonic monuments relating to the utilization and distribution of the waters of the Nile.

It is doubtful whether archæologists have been able to determine the position or define the object of Lake Moeris, that grand work which astonished the ancients. Two or three nilometers in ruined temples are the only vestiges of that interest which was always attached to the flood heights of the Nile. The landing-wharves, masonry dikes, reservoir-walls, bridges, outlets, all those works which would give any valuable indications of the limit of the basins of inundation, their method of supply and discharge, everything concerning irrigation, have entirely disappeared, and the reason is easily explained. That the pyramids and cemeteries have been preserved is because they were constructed on the margin of the desert and built upon the rocks beyond the reach of the water. That the temples erected in low grounds of the valley have been preserved from destruction is because the talus of rubbish which surrounds them has protected them from the direct action of the Nile. Still this protection has not always been sufficient, and we may see to-day, as at Kom Ombo, great edifices crumbling little by little into the bed of the river, which undermines their base. But the works of irrigation, located generally at low points, built upon a soil of mud and of little resistance, have very soon been ruined by giving way of dikes or by the changes of the Nile. Their outlines have been lost during the long centuries of neglect and misery which have so often prevailed in Egypt, and their débris, engulfed by the water or submerged under beds of mud, have disappeared; their position is no longer indicated even by an eddy of the river or an undulation of the soil. Moreover, a very unaccountable fact is established; the walls of tombs, which have transmitted to us the exact representation of the processes employed by the ancient Egyptians in the arts, in agriculture, in trades of every kind, show none of the working parts of their dikes, opening or closing of their dams, or flushing of their canals. In all Egypt, with difficulty, there have been discovered, on two or three bas-reliefs, fellahs employed in raising water for irrigation, as they do still to-day, by means of leathern baskets suspended from the extremity of a lever. Hieroglyphics have always shown us that among the most important functionaries of the country were counted those who had charge of overseeing the canals and distributing the water. Notwithstanding this lack of information, there is such stability in the customs

of the country, and the methods of agriculture and the manual arts differ so little to-day from those represented on the most ancient tombs, that we may infer, without much question, that the processes of irrigation actually in use have been, in great part, bequeathed to the present epoch by the most remote ages, at least those which concern the practices of agriculture, the method of employing the water, its elevation to the level of the land, and all the operations which pertain to the distribution of water. Of the general system of utilization and distribution of the Nile water, which was employed formerly under the Pharaohs, nothing probably remains.

The classic land of irrigation, as it is customary to designate Egypt, hides no secret, sanctioned by time, for a better management of the water of the great river, and even in the existing method we should not seek for very perfect means for regulating the water or very remarkable dispositions for canals or for other works which serve for irrigation. The great works undertaken since the beginning of the century by Mehemet Ali and his successors have generally been designed and executed without a complete plan carefully studied; many of them have never been finished; nevertheless they have increased in a considerable degree the productive power of Egypt, and in this point of view it has appeared to me of interest to report them.

On the other hand, I have thought it would not be useless to call the attention of French engineers to the advantages and inconveniences of the great derivations, really artificial rivers, which irrigate Upper Egypt and the entire delta, and which might be applicable, if not in France itself, at least to the deltas of the large rivers of our possessions in the extreme Orient. Finally, it seems to me that there would always be some valuable information to be obtained from a knowledge of the method and results of irrigation in a country where it has been employed for a long time, and where it not only produces the wealth but is its only resource.

Such is the spirit in which I undertake this work. I have endeavored to expound facts concerning general information which can be made available for the art of irrigation, passing over as a side issue the peculiarities and specialties, which are of no interest outside of Egypt. I have not treated the historical branches of the subject; it has elsewhere been treated in detail, both by the great work of the French expedition and by Linant de Bellefonds in his books on the public works of Egypt.

I will confine myself, then, at first, to giving some general ideas about Egypt, her climate and soil, then about the Nile and the different systems of irrigation adopted in the country. I will afterwards pass in review each region, describing the principal canals and works there found; then I will explain the method of execution and maintenance of public works; after having investigated the employment of water for the various crops and the method of using it by the rural proprietors, I will attempt to indicate the benefits the land derives from a good irrigation; and finally I will explain the laws and regulations governing the matter.

I have stated above that the great works of irrigation in Egypt have been heretofore badly arranged. European engineers of every nationality, and among others distinguished French engineers, have attempted for a long time to create an organization for the system, and have elaborated for this purpose numerous projects, but although they have done much to perfect the method of using the Nile water, they have usually been hindered in this enterprise either by the will of the sovereign, the inertia of the proprietors, or the resistance of the population. Events of the last years have placed the whole service of irrigation in the hands of English engineers, who, profiting by the freedom of action which the present situation of Egypt affords them, are attempting, at present, to improve and complete the works of their predecessors. I will say a few words in concluding this investigation as to their projects and the works in process of construction.

I will confine myself in all that follows to that portion of Egypt which is to the north of the first cataract of the Nile, at which point cultivable Egypt really begins.

CHAPTER I.

GENERAL INFORMATION CONCERNING EGYPT AND THE NILE.

GENERAL DESCRIPTION OF EGYPT—THE NILE—COMPOSITION OF THE SOIL OF EGYPT—NATURE OF THE WATER AND MUD OF THE NILE.

I. GENERAL DESCRIPTION OF EGYPT.*

Extending from the first cataract, at Assouan, to a few kilometers north of Cairo, the valley of the Nile proper takes the shape of a long and narrow ribbon of land, having a general trend from north to south; it extends from the twenty-fourth to the thirtieth degree of north latitude for a distance of nearly 900 kilometers. The maximum width of the valley hardly exceeds 25 kilometers, the mean is from 12 to 14 kilometers.

The surveyed area of this portion of Egypt, which is generally designated under the name of Upper Egypt, is about 1,007,900 hectares.

In Upper Egypt the valley of the Nile is inclosed, on both sides, between arid and desert plateaus, which extend on the one hand to the Red Sea, and on the other hand to the eastern limit of the Sahara; thus inclosed between vast and desolate regions, deprived of moisture and unsuitable for any vegetation, it is a true elongated oasis. The border of these two long plateaus present to view abrupt cliffs in some localities, in others ranges of hills. They are called, on the west, the Libyan chain, and the Arabian chain on the east. The crests of these two ranges seldom rise higher than 200 or 300 meters above the level of the river, generally they do not exceed 50 to 100 meters in height.

At two points, Gebel Oilella, situated 68 kilometers north of Assouan, and at Gebel Ein, which is a few kilometers below the former point, the valley is so crowded between the rocky counterforts of the Libyan and Arabian deserts that it is reduced to the very bed itself of the Nile.

In the Libyan chain, 90 kilometers south of Cairo, there is a pass behind which extends a depression, circular in form, about 40 kilometers in diameter. This pocket of low ground, scooped out of the surface of the desert and fed with water by a supply from the Nile, is called Fayoum. It is considered as forming a part of Upper Egypt, and has a surveyed area of 123,300 hectares. It is generally supposed that Lake Moeris extended formerly over a portion of this province.

A short distance north of Cairo begins the Delta or Lower Egypt, which is composed of three parts.

The first, which is the Delta proper, is comprised between the two branches into which the Nile divides, a few kilometers below Cairo, and which are the only two now remaining of the seven ancient arms; the Rosetta arm on the west and the Damietta on the east. The Delta forms a triangle with an altitude of 160 kilometers and a base of 140 kilometers; it includes a surveyed area of about 720,300 hectares.

The second part of Lower Egypt, to the west of the Rosetta arm, is an elongated triangle, whose apex is a little below the separation of the two arms of the Nile, and whose base along

* See Plate I, General Map of Egypt.

the sea extends for about 70 kilometers in length. The surveyed area of this portion is about 168,500 hectares.

Finally, the third part of the Delta stretches to the east of the Damietta; it also forms a triangle whose base along the sea, between Damietta and Port Said, is 60 kilometers long. The surveyed area is 513,800 hectares.

The surveyed area of Lower Egypt is then about 1,402,600 hectares, but this does not include the area occupied by the series of lakes which extend along the base of the Delta, and which are separated from the sea by a chain of littoral dunes. These lakes cover a total area of nearly 400,000 hectares.

From the two borders of Lower Egypt, to the east as well as to the west, begin, without geological change, on one hand the great Libyan Desert, and on the other the desert of Arabia, crossed a little farther by the Suez Canal.

The surveyed area of Egypt, not including the lakes in the north of the Delta, is then as follows:

	Hectares.
Upper Egypt.....	1,007,900
Lower Egypt or Delta.....	1,402,600
Total	2,410,500

The total area of the country, including uncultivated land, lakes, marshes, etc., may be estimated as about 3,000,000 hectares. Thus the Nile from Assouan to the sea has a length almost equal to that of the Loire, and the entire area of Egypt corresponds almost to the area of the five French departments.

The total stationary population of the valley proper, from Assouan to the sea, is 6,302,336, according to the last census of 1882. This represents 210 inhabitants per square kilometer. The population of Belgium, which is the densest of all Europe, is only 187 inhabitants per square kilometer. Egypt is therefore a country relatively populous.

The climate in Upper Egypt is dry and hot; there is no rain, or at least it rains very rarely. Thus, at Cairo, where the heat is a little less than in Upper Egypt, the mean temperature is 20°·9 centigrade for the year, 13°·4 for the three months of winter, and 26°·8 for the three months of summer, according to observations taken at the Khedive's observatory at Cairo.

The amount of annual rain-fall is insignificant; it does not exceed a mean of 26.8 millimeters.

In the Delta the temperature is modified; the rain becomes more abundant as one approaches the sea, and at Alexandria, from observations taken for many years by M. A. Pirond, the mean temperature is 20°·7 centigrade for the entire year, 15°·4 for the three winter months, and 25°·6 for the three summer months; the annual rain-fall in this city is 212.3 millimeters.

With such climatic conditions, and with the vicinity of immense deserts, the evaporation from the surface of the Nile, canals, and irrigated lands should be considerable; but there have been no exact observations to fix the importance of this phenomenon.

M. Linant de Bellefonds reports that observations, taken for two years without interruption, have enabled him to fix the mean evaporation at 9 millimeters daily. This amount appears excessive; it is probable that it resulted from observations made on small reservoirs, although M. Linant does not specify the nature of the observations which lead to this result. On the other hand, during the construction of the Suez Canal, and at the time of the opening of the Bitter Lakes, M. Lavalley made observations on a large scale, from the month of March to the month of August—that is to say—during the hot season, and he finds that over this great surface of water the evaporation each day was only 3 to 4 millimeters. This is the amount which was accepted in 1882 by the commission officially charged to examine, in France, the project for the interior sea of Gabes as representing the probable evaporation from the surface of the projected sea in a climate analogous to that of Egypt.

It must be admitted, however, for canals which do not contain a large quantity of water, for the inundation basins, generally subject to the action of the continuous winds which prevail in the Nile valley during flood, that the total of 3 to 4 millimeters is below the true mean evaporation.

I will avoid, as much as possible, the employment of foreign names, little familiar to the reader, in speaking of the territorial divisions of Egypt; nevertheless I will necessarily be

obliged to cite them to give more clearness to the subject. I prefer to indicate here the nomenclature of the fourteen provinces into which the country is divided. They are administrative divisions, which correspond nearly to what are departments in France.

	Surveyed area in hectares.	Population.
UPPER EGYPT.		
The provinces below are enumerated descending the course of the Nile from south to north.		
Provinces:		
Esneh	65, 700	110, 630
Keneh	128, 500	883, 819
Guirgneh	149, 200	515, 972
Siout	180, 700	549, 776
Minieh	181, 200	294, 655
Beni-Souef	92, 000	193, 305
Fayoum	123, 300	200, 967
Quizeh	87, 300	274, 406
LOWER EGYPT.		
<i>East of the Damietta arm.</i>		
Provinces:		
Galoubieh	81, 400	254, 198
Charkieh	218, 200	435, 880
Dakalieh	214, 200	578, 144
<i>Between the two arms of the Nile.</i>		
Provinces:		
Menoufieh	156, 400	642, 609
Garbieh	563, 900	908, 041
<i>West of the Rosetta arm.</i>		
Province of Behera	168, 500	364, 050
Total	2, 410, 500	
Add for the population of a few cities not comprised in the provinces enumerated above:		
Cairo		352, 416
Alexandria		181, 200
Damietta		43, 500
Rosetta		19, 267
Total population of Egypt		6, 302, 836

II. THE NILE.*

Burnt from one end of the year to the other by a sun that rarely hides itself, and deprived of the kindly influence of rain, Egypt only exists by the Nile, and this river, in order to carry to her the tribute of its fecundating waters, produced by tropical rains, is obliged to meander for many thousand kilometers between arid banks and savage rocks without a single affluent, a single drop of water from the heavens, coming to compensate the losses from infiltration and evaporation.

At Khartoum, about 15° 40' north latitude, the Nile is really formed by the junction of the two great equatorial rivers called the White Nile and the Blue Nile. A little to the north of Berber, about 17° 40' north latitude, the discharge of the river is again added to by a last affluent, the Atbara, which, dry a part of the year, brings to the Nile all the waters of the northern portion of the mountains of Abyssinia; but from Berber to the sea, a course of nearly 3,000 kilometers, no new water comes to the river. From Assouan to the sea the Nile flows in a bed excavated in the midst of layers of mud which it has successively deposited in the bottom of its valley. The latter, quite narrow below Assouan, enlarges at the thirtieth kilometer below to form a vast plain above Gebel Oileileh, a point where, as above said, the river passes a rocky defile which is about 400 meters wide.

* See Plate I, Map of the Nile.

Below this point the width of the mud region and bottom of the valley increases gradually and assumes presently mean normal dimensions of 12 to 14 kilometers. Nothing hinders its course in the midst of these deposits, which lose their resistance by contact with the water. The Nile forms a channel sometimes almost rectilinear, at others very tortuous, caving its banks on one side, accumulating the mud on the other, flowing thus in a bed which changes every year, at one point pushed aside by villages which seek to preserve themselves from destruction, at another thrown to the middle of the plain by the mountains which bound the valley.

In all Upper Egypt the bed of the Nile is almost constantly carried to the right side of the valley, and flows quite frequently along the very foot of the limestone cliffs which bound it. Most of the cities and farms are found here on the left bank of the river.

The width of the Nile is very variable. During low water the river wanders between vertical banks and bars of sand and mud; ordinarily it is separated into several channels; the level at this stage is from 8 to 10 meters below the surface of the soil near Assouan, and from 5 to 6 meters near the apex of the Delta. During mean stage the Nile flows bank-full, with a width between banks from 500 meters to 2 kilometers, and is often divided into many channels by islands, which are frequently many kilometers long. It is narrowest opposite Cairo. The construction of wharves and the closing of the ancient sloughs have reduced the width to 240 meters. The depth at this point reaches 12 to 15 meters at low water. Finally, during high water the greater bed of the stream, for the most part, would be the entire valley, were it not that the river is confined by dikes, more or less distant from the banks and sufficiently high to protect the land from overflow.

From the apex of the Delta to the sea the two arms, the Rosetta and the Damietta, into which the Nile divides, behave nearly like the principal trunk; we have the same irregularities of bed, the same displacements of current. The Damietta arm, which is the less important of the two, presents generally a less width throughout than the Rosetta. Both arms flow through the midst of alluvium, remote from mountains and deserts, except that for the upper 40 kilometers of its course the Rosetta arm borders the Libyan desert.

Low water, which is from 4 to 5 meters below the general level of the soil at the apex of the Delta, is not more than 1 meter below the soil level at the mouths. As for the floods, were they not retained by dikes they would often inundate the greater part of Lower Egypt, since the level of the ordinary floods here is at least 1 meter above the general level of the land.

Although the Damietta and Rosetta arms are the only ones which at present exist, all the ancient arms are actually found either filled up or converted into derivations or canals; it would not be exact to say that the Rosetta and the Damietta were the only mouths by which the river empties into the sea. The Nile, in fact, throws a part of its waters for the entire year, or during flood only, according to circumstances, by natural or artificial derivations, or by drainage canals, into a series of lakes which form, as it were, a girdle at the base of the Delta. These lakes are separated from the sea by a chain of littoral dunes, resting on the alluvial mud which comes from the Nile, and is pushed along the sea-shore by a littoral current acting from west to east. Each of these connects with the sea by an opening or mouth, which permits them to discharge the surplus water that the Nile sends them, and which should be considered true mouths of the river. These lakes are: Lake Edkou, to the west of the Rosetta arm, covering 34,000 hectares; Lake Bourlos, which extends between the two arms of the Nile for about 80 kilometers in length parallel to the sea-shore, having a mean area of 112,000 hectares; and, lastly, Lake Menzaleh, to the east of Damietta, which has been crossed by the Suez Canal, and is about 60 kilometers long and about 150,000 hectares in area. Two other littoral lakes are situated to the west of Lake Edkou; they are Lakes Aboukir and Mariout, their combined area is about 100,000 hectares; they also receive some water from the Nile by means of irrigation and drainage canals, or by infiltration, but they have no outlets on the side of the sea.

Taking the general direction of the valley, without considering the numerous bends traced by the course of the Nile, the total length of Upper Egypt, from Assouan to the apex of the Delta, is about 860 kilometers, the length of the Delta, following in like manner the same general direction of either arm, is about 170 kilometers. Measured under the same conditions, the mean longitudinal slope of the valley, little variable from one point to another, is about 9 centimeters per

kilometer for Upper Egypt and 10 for the Delta. But if we measure the detours which the mean course of the river takes, the length of the Nile would be 1,000 kilometers from Assouan to the apex of the Delta, and from this point to the sea would be 266 kilometers by the Rosetta arm and 272 kilometers by the Damietta, being an increase of 16 per cent. in Upper Egypt and 55 and 59 per cent. in Lower Egypt over the length of the valley in the Delta as indicated above. Under the same conditions, the profile along the banks of the river has a slope in Upper Egypt of 75 millimeters per kilometer, 66 millimeters per kilometer following the Rosetta arm, and 65 millimeters per kilometer along the arm of Damietta. The mean slope of the river between Assouan and the Delta may be considered, either at low water or at flood, as nearly equal to the slope of the banks, or 75 millimeters per kilometer; however, it is somewhat less at low water, the current making detours. In the Delta the slope of the water is somewhat greater than the slope of the banks at flood; floods may exceed by more than one meter the level of the land at the junction of the two arms of the Nile. During low water, on the contrary, the river may fall 5 or 6 meters below the land level at the apex of the Delta. The water slope in Lower Egypt is more gentle than that of the banks, and may be as low as 42 millimeters per kilometer.

According to levels, undertaken and interrupted at different attempts, and which have just been completed, the mean level of the arable lands in the neighborhood of Assouan is 94 meters, and at the apex of the Delta 17 meters, above the mean level of the Mediterranean.

As in every valley where a river flows, cutting its bed in the midst of its own alluvium, Egypt has a transverse slope from the banks of the Nile to the boundaries of the desert. Thus in the province of Guirgneh the cultivated land which is situated near the river is higher than that which extends to the foot of the western mountains, by 50 to 90 centimeters, for a total valley width of from 5 to 6 kilometers. In the south of the province of Beni-Souef, where the valley is from 12 to 15 kilometers wide, this difference is between 80 centimeters and 1.20 meters.

The same phenomenon is presented in the Delta; the banks of the two arms of the river here are higher than the land farther back; also the banks of the Damietta are higher than those of the Rosetta. If the levels of these two arms are taken on the same line from east to west, we find, about the middle of the Delta, where they are about 50 kilometers apart, that the Damietta arm is 1.30 meters higher than the Rosetta; also that in this middle portion the difference of level of the two arms is the greatest. In this same middle region of the Delta, and to the east of the Damietta arm, the transverse slope of the soil from the river is only from 2 to 3 centimeters per kilometer.

All these transverse slopes are then quite gentle.

The regimen of the Nile is very remarkable for its great regularity. Every year the river begins to rise, in Egypt at the end of June, the water rises until the end of September, then falls, very rapidly at first, slowly afterwards, until the month of June of the following year. Every year the phenomenon is repeated in the same manner, with slight variations in the level of the low water and floods, and the dates of the maximum and minimum of the water height. Therefore in Egypt those sudden, accidental, and unexpected rises are not apprehended, which cause so much disaster along our rivers and which give so much uneasiness to engineers.

The regularity of this annual flood occurs because the Nile is fed exclusively by periodical tropical rains, and because the contributions from irregular rains, such as occur in the temperate zones, do not disturb the normal flow of water until the following year. The three great affluents of the Nile are on one side, the Atbara and Blue Nile, which both take their rise in Abyssinia, and on the other the White Nile; this latter is formed about the ninth degree of north latitude, by the junction of the three great rivers, the Bahr-el-Gebel, which flows from the great equatorial lakes, the Sobat, and the Bahr-el-Gazal, the first from the east and the second from the west, both having their principal sources between the ninth and sixth degrees of north latitude.

The Blue Nile and the Atbara appear to have almost the same discharge; the Atbara is more rapid, and remains dry a part of the year; at its mouth it is about 500 meters wide. These two affluents bring to the Nile the mud which they have taken from the plains of Abyssinia.

The equatorial lakes begin to empty their waters into the White Nile in the month of April; the rains then pass to the north and fill the Sobat and Bahr-el-Gazal, which hold up the floods produced by the Bahr-el-Gebel. The White Nile rises at Kahrtoom about the end of April and

falls from the beginning of September. This river is the first to send its waters to Assouan at the end of June, about forty days after they arrive at Kahrtaum; this river also, on account of the storage of water in the equatorial lakes, and the immense marshes through which it flows, maintains the high level of the Nile in Egypt after the Atbara and Blue Nile, which are more variable and torrential, have regained their beds; the maximum of the flood of these last rivers, which occurs in August, reaches Egypt in September. Thus the White Nile, the outlet of the great lakes, is the regulator; the Blue Nile and the Atbara give the flood its strength; these are the principal factors that make up the regimen of the Nile.

From the more or less want of concordance which exists each year between the epochs of the flood of the Atbara, the Blue and White Nile, there necessarily results for Egypt corresponding differences in the level of maximum flood and in the dates of this maximum. This is in fact what occurs, and although the phenomenon of the Nile flood as a whole may be the most regular in nature, nevertheless it undergoes every year variations which render the utilization of the high water more or less difficult for irrigation, and causes the flood to be insufficient, good, or too much for Egypt.

At Assouan—that is, at its entrance into Egypt—the limits between which these changes in the regimen of the river may occur from year to year are as follows:

(1) The epoch of maximum flood is always between the 15th of August and the 1st of October.

(2) During the period of ten years, from 1872 to 1881, the level of lowest water has varied between the limits of 84.29 and 86.89 meters above the Mediterranean, which gives a difference of 2.60 meters between the extreme limits of low water.

(3) During the same period of ten years the level of the highest flood has varied between the limits of 91.40 and 94.15 meters above the Mediterranean, which gives a difference of 2.75 meters between the extreme limits of the floods.

In Egypt it is customary, by tradition, to compare the floods by the indications of the gauge at Cairo; but if the regimen of the Nile is to be studied, it is preferable to use the gauge at Assouan, because at this point the filling or emptying of the basins of inundation, the feeding of the canals, or the diking of the river have not influenced the discharge or water levels. However, as the levels which the Nile assumes each year at Cairo at low water and flood are of great importance to Lower Egypt, it is useful to record them.

During the period of ten years, from 1872 to 1881, the low water of the Nile has varied between heights of 11.49 and 13.76 meters, which gives a difference of 2.27 meters between extreme stages. These results are now modified by the rise of water obtained by the great dam at the apex of the Delta.

On the other hand, Col. Scott Moncrieff, under Secretary of State to the Ministry of Public Works, in his note on irrigation in Egypt for 1884, gives the following information concerning the flood levels at Cairo for the last one hundred and twenty-six years ending in 1885, inclusive:

NILE LEVEL.

	Meters.
5 years above the limit of	20.12
24 years above the limit of	19.58
28 years above the limit of	19.04
21 years above the limit of	18.50
19 years above the limit of	18.23
13 years above the limit of	17.96
11 years above the limit of	17.69
4 years above the limit of	17.42
1 year above the limit of	17.15

Total.. 126

This table shows a difference of about 3 meters between the extreme floods.

To resume, the mean rise of the Nile is about 8 meters at Assouan and 7 meters at Cairo, with a maximum variation of 2.50 and 3 meters in the extreme limit of the low water and of the flood.

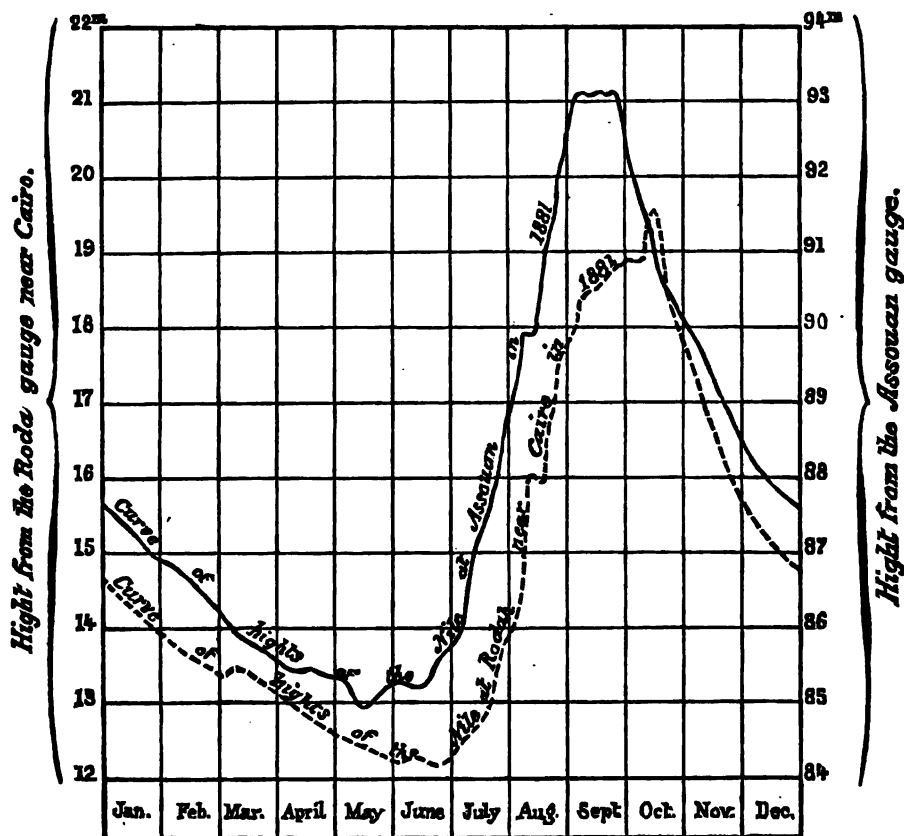
On the following diagram are represented the hydrographs at Cairo and Assouan for the year 1881, which may be taken as corresponding to an ordinary state of the Nile regimen. This year at Assouan the Nile fell gradually about 2.50 meters, with a regular rate, from the month of January to the beginning of May, then it remained almost stationary until towards the 15th of June; at this time it began rising, and rose 7.50 meters up to the 1st September, about two months and a half; this level was maintained until about the 20th September, then it fell again about 5 meters until the 1st January, 1882, a little more than two months.

On this curve the flood of the different affluents which contribute to form the total flood are not very distinctly marked, they are almost confounded with each other; in other years they can be seen indicated by many maxima sharply separated and succeeding each other at intervals of three weeks or a month, during which the water falls at times 1 meter, rising again.

In 1881 the curve at Cairo followed that at Assouan with a little retardation and with less amplitude in the total rise; here the water does not begin to rise till the beginning of July and continues until about the 10th September; after this date the curve rises again very slowly, then it makes a sudden jump about the 10th October; the continual upward direction from the 10th of September and this sudden jump, which showed a supplementary flood of about 1 meter, are produced by the emptying of the basins, which goes on about this time of the year. The curve falls then to the 31st of December, at first quite fast, then more slowly.

These curves serve to give a general idea of the annual regimen of the Nile:

Highs of the Nile at Cairo and Assouan in 1881.



Scale of days...0.00025 meter = 1 day.

Scale of highs.....0.01 meter = 1 meter

The mean velocity at low water is naturally variable from point to point, the bed of the Nile presenting great irregularities; however, above Cairo it may be stated that during low water, in a section where the water is well collected, the mean velocity is from 450 to 500 millimeters per

second. The engineers of the French expedition found 645 millimeters as the mean velocity at flood height.

It has been determined, from observations taken at various epochs, that the discharge of the Nile in Egypt, at the lowest stages, may be estimated at 460 cubic meters per second; during mean flood this discharge is raised to 13,000 cubic meters per second, from observations taken at Ilcileh by Linant de Bellefonds. If we compare these amounts with those given for French rivers, we find that at Beaucaire the discharge of the Rhone during low water is 400 cubic meters per second, a little less than the minimum discharge of the Nile, and that at the same point during the highest flood the same river discharges 13,900 cubic meters, a little more than the Nile at mean flood.

It is useless here to speak of the regimen of the Nile below Cairo, because the works and canals which have been constructed for the distribution of water among the lands to be irrigated, have created in the two branches of the Delta an entirely artificial condition. The investigation of this will be more in place in the chapter where will be considered the irrigation of the provinces which border these two branches.

Formerly, when Egypt held Khartoum and Berber, the gauges established in these two cities permitted the announcement of the Nile movements a long time before they were transmitted to Assouan, because the water took forty days at the beginning and thirty days at the end of the flood to pass over the distance between Khartoum and Assouan. The result was great security for the country, which had thus all the time necessary to strengthen the dikes and protect the works when the nilometer of the upper river announced an exceptional flood.

At present, as Egypt holds the course of the Nile only as far as Onadi-Alfa—that is, as far as the second cataract—this is the point at which is established the farthest gauge; the water takes four to six days only to pass from this station to Assouan, and it comes from Assouan to the point of the Delta in from nine to eleven days, according to the stage of the flood. It has therefore become very difficult to become forearmed in Egypt against the effects of the great floods.

III.—COMPOSITION OF THE SOIL OF EGYPT—NATURE OF THE WATER AND MUD OF THE NILE.

The geographic and climatic conditions existing in Egypt and the peculiarities of the Nile regimen having been summarily indicated, there still remain to be examined the quality of the soil, as well as the composition of the water and mud of the Nile, to have passed in review all the elements which characterize the country in reference to irrigation.

The soil of the Nile valley in Upper Egypt, as in the Delta, is formed by the alluvial deposits of the river. At the period of low water, when the level has fallen to 7 or 8 meters below the surface of the cultivated lands, if we go over the river following the bank at one of the many places where the river undermines its base and cuts it almost vertically, and if we observe the section of the earth thus exposed, we recognize readily the different varieties of which the alluvium is composed; some layers very argillaceous and fissured stand vertical, others more sandy show little cohesion, and finally from point to point banks of almost pure sand assume a long slope, these sands alternate in layers, more or less thick, between the argillaceous mud. The mud deposits extend to more than ten meters in height above the bottom of the river bed; below are found sand and gravel, then, still deeper yet, beds of clay.

In the vicinity of the apex of the Delta the beginning of the sand and gravel is at a depth of twenty meters below the surface, the clays are at a depth of twenty-five meters, and it is about the same in Upper Egypt. Borings to great depths, made in Upper Egypt in 1848 by the Government, seem to indicate that the solid foundation upon which the alluvium rests is composed of chalk, sandstone, and schists; the border of the rocky basin which limits the Nile valley is formed of calcareous deposits from the sea as far as Gebel Ilcileh—that is, for almost the extent of Egypt, beyond Gebel Ilcileh sandstone replaces the limestone, and at Assouan it is replaced by granitic rocks.

The stratum of vegetable mold which forms the arable land of Egypt is of considerable depth; it is in general an alluvial clay, whose chemical composition is quite uniform in Upper as well as Lower Egypt.

From numerous analyses, made in 1872 at Paris under the direction of MM. Payen, Champion and Gastinel Bey, it contained about—

	Per cent.
Silica	45
Clay	53
Magnesia	20 to 1.60
Lime	1.30 to 4.90
Nitrogen	0.03 to 0.10
Phosphoric acid	0.03 to 0.32

As we approach the Mediterranean the soil contains more or less sodium chloride, in the middle of the Delta it goes as high as 4 per cent.

In general the Egyptian soil contains too much silica, clay, and iron oxide, and has very little lime, small quantities of phosphoric acid, and little organic matter; the portion of this latter material hardly exceeds 4 to 9 per cent.

What is the composition of the water destined to fertilize this land?

In addition to the humidity which they afford the land, and which they alone can provide in the dry climate of Egypt, the Nile waters effect vegetation by the materials which they hold in solution and those carried in suspension.

Up to the present the most complete study of the chemical nature of the water and mud of the Nile is that of Dr. H. Letherby, professor of chemistry in the College of the London Hospital, at the time of the irrigation projects, which the English engineer John Fowler proposed in 1876 at the invitation of the ex-Khedive Ismail. The analyses by this chemist were made of samples taken from the Nile at Cairo, each month during the entire year, from the month of June, 1874, to the month of May, 1875. The results given below are taken from these analyses. The quantity of ammonia, obtained from the saline and organic matters held in solution by the Nile water, varies from 114 to 270 milligrams per liter, averaging 176 milligrams.

This proportion is slightly different from what is known of the different European rivers; thus the water of the Seine, above Bercy, contains 60 milligrams of ammonia; the Thames, at Hampton, the point from which the water for the use of London is taken, contains from 85 to 157 milligrams, and Dupuit states that 150 milligrams per liter is the maximum amount of ammonia which should be contained in potable water. The amount of other soluble matter in the Nile is shown in the table below; it shows, for the purpose of comparison, the mean proportion of soluble matter of the Seine water above the junction of this river with the Marne. The amounts are given in grams per liter of water.

	Nile.	Seine.
Lime	0.0424	0.0023
Magnesia	0.0100	0.0080
Soda	0.0062	0.0087
Potash	0.0144	
Chlorine	0.0067	0.0043
Sulphuric acid	0.0216	0.0108
Silica	0.0087	0.0078
Organic matter	0.0175	0.0130
Carbonic acid and loss	0.0403	0.0676
Total	0.1690	0.2108

The mean composition of the Nile water, then, presents nothing specially interesting to distinguish it. In fact the total weight of material held in solution differs little from that contained in most rivers of France. The following table is generally accepted as giving this weight:

	Grams.
The Loire	0.135
The Garonne	0.137
The Rhine	0.171
The Rhone	0.184

During the year 1874-'75, to which the analyses cited above refer, the quantity of soluble matter to the liter of Nile water varied between very narrow limits, that is, from 1361 to 2047 tenths
H. Mis. 134—2

of milligrams; it attains its absolute maximum at the moment of highest water on account of the increase in the proportion of lime, soda, chlorine, sulphuric acid, and organic matter. Another maximum is attained during the extreme low water, owing to the increase in quantity of potash, silica, organic matter, and carbonic acid. But it would be necessary to verify the yearly recurrence of these phenomena before deducing a general law from these data.

On proceeding to the examination of the amount of matter held in suspension, it is found to be very variable from one month to another; in fact every flood brings into Egypt water known in the country as the "red waters," which are charged with a considerable amount of sediment brought from the plains of Abyssinia by the rapid currents of the Blue Nile and the Atbara; but as soon as the great wave of the flood passes, the proportion of sedimentary mud decreases rapidly, the Nile loses its red color, which it for a short time had attained, and the water resumes its ordinary yellow.

In the table below the amount of material in suspension for the year 1874-'75 is shown in grams per liter:

	Minimum.	Maximum.	Mean.
Organic matter	0.0051	0.1841	0.0413
Mineral matter	0.0383	1.3074	0.2713
Total	0.0434	1.4915	0.3126

The epochs of minimum as well as maximum occur at almost the same time for organic matter and mineral materials; it seems generally that the proportions of organic matter which enters into the composition of the Nile mud is not very large. During the first days of each flood, while the river is still but slowly rising, it always assumes a green color, which is given to it by the vegetable detritus drawn from the vast equatorial marshes by the first rise; during this short period, which lasts rarely more than from 8 to 15 days, and which on this account has escaped the analyses given above, the Nile is charged with little mud and much organic matter.

During the twelve months comprised between the two successive stages, the Nile transports about 54,000,000 tons of alluvium at the rate of 444 grams on the average to a cubic meter of water. This quantity represents a total volume of 30,000,000 cubic meters, at least half of which is deposited during the two months nearly which correspond to the maximum of the flood. By commonly accepted data, this volume of sediment is one-half greater than that carried by the Rhone to the sea in the same length of time. The Po discharges annually one and a quarter, the Danube twice, and the Mississippi six times as much material in suspension as the Nile. On the other hand the Durance, whose mud and sediment enjoy a well-merited notoriety, during the year 1860 had its waters charged at the average rate of 1.454 kilograms per cubic meter, almost equal to the established maximum of the Nile for the year 1874.

Thus, in spite of legendary repute, the Nile ought not to be considered a very extraordinarily sedimentary river, although it may have been heretofore, when it built up, by its deposits, the entire surface of the Delta.

The mean composition of the Nile sediment, according to Dr. Letherby, is as follows:

	Samples taken—	
	During flood.	During low water.
Organic matter	15.02	10.37
Phosphoric acid	1.78	0.57
Lime	2.06	3.18
Magnesia	1.12	0.99
Potash	1.82	1.06
Soda	0.91	0.63
Aluminum and iron oxide ..	20.92	23.55
Silica	55.09	58.22
Carbonic acid and loss	1.28	1.44
Total	100.00	100.00

From other analyses, made by MM. Payen, Champion, and Gastinel Bey, the sediment of the Nile contains from 0.091 to 0.13 per cent. of nitrogen, but the samples tested by these chemists contain only traces of phosphoric acid.

Referring to the foregoing table, we observe that during flood, or at the time when most irrigation is going on and the basins of Upper Egypt are being submerged, the Nile sediment contains the greatest quantity of organic matter, phosphoric acid, and potash; the proportion of these ingredients, which are energetic fertilizing agents, diminishes greatly during low water.

The soil of Egypt has almost the same proportion of sand, clay, and lime as the sediment itself. It is also worthy of remark that this sediment differs notably, in its chemical composition, from the ordinary alluvium of French rivers, which contain many more calcareous elements, but often less nitrogen and phosphoric acid.

Thus the sediment of the Durance, which may be taken as a type, contains 36 to 49 per cent. of argilo-siliceous matter, 32 to 44 per cent. of carbonate of lime, 10 to 20 per cent. of various materials containing nitrogenous organic substances, and an average of .08 per cent. of nitrogen.

The sediment of the Rhone contains 49 per cent. of insoluble residue, 10 per cent. of peroxide of iron, 32 per cent. of carbonate of lime, and 9 to 10 per cent. of various organic substances containing an average of 16 per cent. of nitrogen.

On the other hand, the "tangues," which are considered a valuable manure, are composed generally of 41 to 71 per cent. of siliceous sand, 23 to 52 per cent. of carbonate of lime, 3 per cent. of organic matter, and 1.50 to 7.50 per cent. of various substances, among which are magnesia, alumina, iron oxide, chlorine, phosphoric acid, soda, potash, salts of lime, nitrogen, etc.

Finally the soil of the Bay of Mount St. Michael, a very rich alluvium, is formed of calcareous sand containing from 3 to 5 and 6 per cent. of organic matter with 0.13 to 0.45 per cent. of nitrogen, 32 to 40 per cent. of carbonate of lime, 1.50 to 2.6 per cent. of phosphate of lime.

The sediment of the Nile therefore may be classified among the alluvia richest in fertilizing materials, although it is deficient in lime. Agriculturists have also acknowledged for a long time that the crops which require the least amount of this material are those which succeed best in Egypt.

Having concluded this study of the soil of Egypt and of the waters of the Nile, it is necessary to mention a fact of great importance in reference to irrigation. Whenever a well is sunk in Egypt, through the alluvium deposits, at a certain distance from the river, to the limit of infiltration, it is found that the water drawn from these wells differs entirely, in its chemical elements, from the Nile waters. This peculiarity is shown plainly in the table below, which contains the mean composition in grams per liter of the water drawn, during low water, from three wells situated on the left bank quite a distance from the river:

	Well water.	Nile water.
Ammoniacal salts.....	0.000087	0.000061
Ammonia from organic matter in solution.....	0.000087	0.000110
Materials in solution:		
Lime.....	0.1856	0.0434
Magnesia.....	0.0453	0.0100
Soda.....	0.0820	0.0620
Potash.....	0.0037	0.0144
Chlorine.....	0.1380	0.0087
Sulphuric acid.....	0.0598	0.0216
Nitric acid.....	0.0017	0. Trace
Silica, alumina, and iron oxide.....	0.0180	0.0097
Organic matter.....	0.0080	0.0175
Carbonic acid and loss.....	0.1226	0.0403
Total quantity of solid matter after evaporation.....	0.6402	0.1890

Thus, in filtering through the lower strata of the soil, the water takes up four times as much soluble matter as the Nile water contains; it absorbs in its passage through the ground marked quantities of carbonates, sulphates of lime and magnesia, chlorine, and sodium. Moreover, this

is a general fact in Egypt, all water filtered through the alluvial soil is more or less brackish. Also, whenever the waters of infiltration come to the surface of the soil for sufficient length of time they leave by evaporation a whitish efflorescence and true salt deposits, which render any cultivation at such places impossible. This fact is also produced in the lands which border the canals when the level of the water is a little higher than the adjacent soil. These efflorescences take place more abundantly in the low lands where the water of infiltration has not been properly drained.

This phenomenon has unfortunately caused the ruin of quite extensive regions in Egypt, where the drainage of irrigation water has been too frequently neglected. Thus infiltration is the terror of the Egyptian farmer, who often prefers to have his feeding canals at a lower level than his fields, and to raise the water at great expense, rather than receive it at the level of the land so as to admit of natural irrigation. In all projects for irrigation careful attention should be given to this fatal action of infiltration water.

CHAPTER II.

GENERAL METHOD OF IRRIGATION AND FARMING IN EGYPT.

GENERAL CONSIDERATIONS—INUNDATION BASINS—METHODS OF IRRIGATION.

I. GENERAL CONSIDERATIONS.

The Egyptians have always practiced agriculture, both by means of the overflow caused by the Nile floods and by irrigation, but up to a few years ago this latter method was quite the exception. It was only applied in a few favorable localities, where water could be had during a part of the summer at a level a little below that of the soil, either on the banks of the Nile and its arms or elsewhere in certain basins of inundation, notably in Lower Egypt, to supplement the effects of an insufficient overflow.

On the contrary, up to the first years of the present century overflow basins formed the normal system of Egyptian cultivation, both in Upper Egypt and the Delta. With this system of cultivation the peasant had the stage of the Nile to consider; it was the overflow alone which fertilized the country and assured the subsistence of the people. Thus the fellah every year awaited with impatience the first upward movement of the water; the progress of the flood was every day officially announced at the nilometer of Roda, near Cairo, and then proclaimed in the city; public prayers were offered in the mosques when the water did not rise fast enough, and finally public rejoicings marked the moment when the Nile reached the recorded height of 16 cubits at Cairo and the order for filling the inundation basins was given, for a good flood presaged an assured crop for the farmer and abundant revenue to the Government, which calculated the amounts of its receipts by the scale of the nilometer.

A kind of religious fear and mystery always surrounded everything pertaining to the Nile flood. In fact while, according to Arabian historians, in normal conditions it assured for Egypt treasure and crops which sufficed to maintain it for two years, if too low it brought in its train misery and famine, and if too high it caused rupture of the dikes, ravaged the country, and ruined cities and villages.

Mehemet Ali was the first who in Lower Egypt abolished inundation basins and dug canals, designed during low water to carry the water to the land distant from the Nile. His successors followed the impulse which he gave, and at present in the whole delta irrigation has been substituted for overflow. The Khedive Ismail Pasha introduced also culture by irrigation into a part of Upper Egypt, so that to-day inundation basins extend over less than a third of the surface of Egypt.

The producing power of the country has been considerably increased by these transformations. In the irrigation territories the soil is in fact cultivable for the entire year, and is able to produce during summer rich crops, such as sugar-cane and cotton, while the basins only produce a single winter crop after the flood, and then lie idle for want of water.

On the other hand, these new conditions of utilization of the Nile water have led to this result: The regimen not only of the flood is now important to Egypt, but also, and still more, the regimen

of low water, because as the level of low water is more or less high, so the canals are fed more or less easily and give more or less water for the summer crops, which are very much more remunerative.

The magnitude of the flood has not on this account become indifferent to the inhabitants of the plains, first, because great quantities of land are still subject to cultivation by inundation, and, secondly, because in the irrigation territory the high water is used to flood the land for extensive watering of the summer crops, for pushing the intermediate crops a short time under ground in autumn, and finally to prepare the land destined to receive the winter seed. On the other hand, in these same irrigation regions too high floods have become veritable scourges, because the rupture of dikes here invariably leads to the loss of the summer crops, at this time of the year already well advanced.

In considering the various conditions of agriculture in the different parts of Egypt, it is admitted that when the flood exceeds on the nilometer at Roda, near Cairo,

25 cubits* (20.12 meters), it is too high, and dangerous.

23 cubits (19.04 meters), it is good.

20 cubits (17.95 meters), it is weak.

Below 20 cubits, it is bad.

For example, in the year 1877, when the flood only attained the height of 17½ cubits (17.35 meters above sea-level), the country suffered from famine, and the revenue returns showed a falling off of 50,000,000 francs. This fact shows how the height of the flood always affects the welfare of Egypt, though the extension of summer cultivation has rendered the situation much less precarious. Although it is possible, by clearing out the canals or by the artificial raising of the water of the river by means of dikes and training-walls, to counteract in some measure the inconvenience arising from a too low Nile, a low stage in the actual condition of the canals of Egypt is a cause of great perplexity to engineers, because low water occurs at the very time when the richest summer crops have greatest need of water, and a diminution of moisture at this time of the year serves to diminish in a large degree the revenue of the country.

II. INUNDATION BASINS.

Although Egypt is the classic region of inundation, it is not here only that we find annual overflows augmenting and maintaining agriculture. It is known in all the countries of the temperate zone that submersion, practiced regularly while the soil is idle, is one of the best methods of preserving the fertility of the soil, without the necessity of recourse to irrigation when the crops are in the ground.

In his many works on hydraulic agriculture, M. Nadault de Buffon has called attention in many places to this interesting fact, and he has cited numerous examples of land fertilized, without the help of summer irrigation, by simple submersion in winter, either by clear or muddy water.

In Europe this method is only applied on the actual banks of rivers to the portions of the valley which highest water overflows and on which it remains for some time. Most frequently the floods are thus utilized without the previous construction of works of regulation for receiving and storing the water, and the frequent return of these inundations are invited, without which the fertility of the soil would rapidly diminish.

This mode of watering is employed especially on the bottoms, and although clear water is considered good for this operation, agriculturists prefer generally muddy water. According to M. Nadault de Buffon

The mud obtained from natural submersion is subject to no special rule, except to the fundamental condition that the water should run off completely and as much as possible before the epoch of vegetation, because otherwise it proves hurtful to the crops.

In Upper Egypt, where most of the land is subject to annual submersion, and where there would be no cultivation without recourse to the water of the Nile, it was not possible to leave the

* The cubit of the nilometer is 54 centimeters.

care of inundating his fields to the individual initiative of each farmer, especially since the storage of water and emptying of the water in this country demands harmonious labor and methods, without which nothing but disorder and confusion would result. Thus the inundation basins constitute an entire system, which extends from the extreme of Upper Egypt to the apex of the Delta, and in which the regulation of each basin is not only not independent, but closely connected with the method of managing the neighboring basins, and sometimes the whole system of more distant basins.

The essential elements of inundation basins are:

First. A dike parallel to the Nile and sufficiently elevated above the floods to protect the basins against direct inundation.

Second. Two transverse dikes, one above, the other below the basin, and reaching from the Nile dike, either to the hills which border the valley or to the longitudinal dike of an adjoining basin. They are designed to contain the waters of submersion of the basins and separate it from the basins above and below.

Third. A canal supplying the water for the filling and an escape canal for emptying.

As has been said in the preceding chapter, in a cross-section of the Nile valley the lowest point is not found at the very bank of the river, but it is more or less near the border of the valley. Generally it is the line of these points which is utilized at the same time for the supply and emptying of many successive basins in the following manner:

Suppose a series of five basins separated by transverse dikes, each basin having an average area of 5,000 to 10,000 hectares. A feeder, which takes its water direct from the Nile, directs itself towards the thalweg of the valley and carries the water to the first upper basin, situated a few kilometers below the head of the canal. The level of the water at this head, even during the flood, is not sufficient usually to inundate the land in the immediate vicinity. The water enters this first upper basin by one or more regulating works of masonry established in the transverse dike, furnished with sliding timbers serving as dams. Works of the same nature are established in the transverse dikes of the other basins. The inundation water is then carried successively, following the current through these openings, from one basin to another. In maneuvering the shutters of each dam the level of the water is regulated in each basin according to the height of the flood and necessity. As for the basins near the head of the feeder, and which can not be inundated by the waters of the canal itself, which are at too low a level, they are submerged by means of water from upper basins, brought by secondary canals. The supply of one system of basins depends then, more or less, upon basins above, by means of which, by borrowing water, the insufficient inundation of the lower basins may be corrected.

When the land of a system of basins has been submerged a sufficiently long time the outlets which exist in the dikes of the different basins are opened, these basins communicate freely with each other and empty themselves one into the other, and the last empties into the escape canal, which enters the Nile. The river is generally so low at the time of drainage that nothing is opposed to the running off of the water. Sometimes secondary works of discharge are established along the intermediate basins.

The feeder generally has its bottom at a level so high that it is only fed during the maximum of the flood and that its head will be already dry when the basins begin to discharge. When the water of the Nile is slow in falling it is not so; the work at the head is closed with shutters at the desired moment, or if there is no closing work at the head of the canal it is closed simply with earth and stones.

In the present state of affairs the works of communication from basin to basin and those by which the water is discharged into the Nile have not always sufficient openings to assure proper regulation of the level of the basins or a sufficiently rapid drainage of the water; when this case presents itself it is remedied by cutting breaks in the dikes, which each year have to be rebuilt before the flood. This is, however, a primitive and costly proceeding, the employment of which is to be restrained by the construction of new masonry works.

On the left bank of the Nile the series of basins dependent on the same feeder and the same discharge canals are sometimes very extensive; there are two which are particularly remarkable.

The first* extends from Sohag to about 60 kilometers north of Siout, in the two provinces of Guirgneh and Siout. It forms a strip of about 150 kilometers in length, representing an area of 140,000 hectares and divided into twenty-one principal basins. It is almost exclusively supplied by a large canal called Sohagieh, which has its head at Sohag and crosses the whole line of basins, following the thalweg of the valley. The greater part of the drainage water of these basins empties into the Nile a few kilometers above Siout, the surplus drains, at the lower extremity of the series, into the Bahr-Youssef, a water-course similar to the Sohagieh canal, forming, as it were, a prolongation of it, following in the same manner the thalweg of the valley.

The Bahr-Youssef itself serves as a feeder to an important chain of basins, extending to the north of the preceding series more than 200 kilometers and representing an area of about 17,000 hectares. These lands of inundation, divided into sixteen principal basins, are separated from the Nile by a strip 5 or 6 kilometers wide, reserved for irrigation and watered by the Ibrahimieh canal and its branches. They discharge the greater part of their water to the north of the province of Beni-Souef. The surplus is employed to complete the submersion of the basins of the province of Guizeh, which end at the point of the Delta.

In the provinces of Esneh and Keneh, where the valley in general is narrower than in the lower provinces, the series of basins is less developed than those which have just been mentioned.

It is the same along the right bank of the river. The course of the Nile being generally directed to this side, the valley here finds itself blocked from time to time by rocky promontories which prevent the filling of the lower basins by those above. It results that at many points of the right bank submersion can only be accomplished when the Nile level exceeds that of the riparian lands, and this only happens, for portions little elevated, in exceptional years, when the flood reaches, at Cairo, 25 or 26 cubits.

Also on the left bank there lies all along the river a narrow strip of high land which can only be cultivated regularly by submersion at great expense. There would be needed in fact, to inundate them, canals having their heads at too great a distance above, canals which would be of an importance entirely out of proportion to the small amount of land thus made valuable. Therefore these lands only undergo accidental submersion and are most frequently cultivated by irrigation by means of machines elevating from the river itself.

Although the process of filling and emptying the basins, as just described, appears very simple and easy of application, nevertheless in practice the attention and care with which the authorities watch the distribution of the water among the basins determines in great measure the proportion of land submerged and which becomes in consequence fit for cropping; for although the low land receives easily the inundation water, it would sometimes be necessary, in order to bring the water to the more elevated portions, either to overflow temporarily the basins or canals or employ some other device in the management of the works. Besides, as the basins are regulated by series, outlets imprudently made, or too soon or too late, may compromise the crops of certain of them. But the more or less favorable results of inundation depends especially on the manner in which the flood regimen behaves.

If the flood is early, it enters the basins too soon by infiltration or directly; some crops which are made at this time in the lowlands, with water taken with great difficulty from wells dug more or less deep in the mud, are injured before the time of maturity and gathering.

If the flood is late, the epoch of sowing, which is done after the emptying of the basins, passes, and the crops in the ground are subjected to the strong heat of the following spring. If the flood is too little much land is too high to get water or can not remain submerged for a sufficiently long time, or, again, the basins can not obtain water sufficient to assure a good crop.

If the flood is too high, the dikes, which are threatened, demand an increase of surveillance. Finally, if the flood is too long, the heads of the feeders are still supplied at the moment of emptying; the return to the Nile of the discharge water is with difficulty accomplished, and the drying of the ground proceeds too slowly. This shows with what attention the engineer charged with this service of irrigation in Egypt should watch the floods in order to take every possible advantage in regard to culture by inundation.

* See Plates I, II, and III.

The waters of the Nile are introduced into the basins at the moment of the high point of the flood, that is to say, when they are most charged with mud and fertilizing materials; we have seen that at this epoch the Nile contains 1.50 kilograms of matter in suspension per cubic meter.

It is agreed, counting the losses from evaporation and other losses, that a good submersion in Egypt requires 14,000 cubic meters of water per hectare, that is to say, the water in the basins should have a mean depth of 1.50 meters; on the other hand, experience has demonstrated that the inundation water ought to remain on the land, as often as possible, from sixty to seventy days; but it is often necessary to keep below these figures either by the insufficiency of the flood or on account of the arrangement of the basins themselves.

Usually the basins begin to get filled in the first half of the month of August, and they are emptied during the month of October, the epoch of the fall of the flood.

The water remains on the land during a time sufficient to deposit the greater part of the sediment; if it is admitted that it only leaves two-thirds, or 1 kilogram per cubic meter, the other third remaining in suspension, due to the tenuity of the matter composing it, or to the currents and agitation caused in the basins by the wind, the submerged surface would be enriched by a quantity of mud representing 14 tons per hectare, or a layer which would be nearly 1 millimeter thick, supposing it uniformly spread. This mass of sediment contains, among other substances, 15 kilograms of nitrogen and a variable weight of phosphoric acid. These are certainly valuable elements for renewing the fertility of the soil, but alone they would not be sufficient; an average crop of wheat would absorb double the quantity of nitrogen thus afforded by inundation. On the other hand, the amount indicated above, 15 kilograms, should be considered a maximum; because the submersion can not be accomplished everywhere with water very rich in sediment, and it is often necessary, on account of peculiarities of the flood or certain local conditions, to use water already partially settled, comparatively clear. If the soil of the basins preserves its power of production for so long a time, without requiring the peasant to have recourse to fertilizers for maintaining it, it is because the water itself, independently of the matter held in suspension, exerts a specially fertilizing influence on the interior of the arable deposits. Whatever may be the causes and nature of the action, it is a fact readily proved that it assists; after the water is withdrawn from the basins the land gradually dries out and, since it is very argillaceous, it contracts, cracks, and is very soon cut up by numerous and deep crevices which reach to the interior of the soil and divide into fissures more or less narrow. During the whole idle season of the land the soil is thus perfectly prepared by a thorough aeration; the oxygen and nitrogen of the air penetrate into the ramifications of the crevices and enter into intimate contact with the earthy particles throughout the entire thickness of the active layer of the soil. The inundation water comes afterward, loaded with this air, which is in a very divided state, and therefore more apt to be easily absorbed and transformed into products which will afterward be assimilated by the roots of the plants.

This complete aeration of the soil during the drying period of the basins presents also another very marked advantage for the farmer, namely, as soon as the water is drawn off and the soil, still moist, has become fit to receive the seed, there is no need of the laborer; a mere harrowing to mellow the superficial deposit is required. Whatever may be the chemical or physical action of the water in the inundation basins, it is nevertheless the fact that the farmers desire above all things the "red water" for their submersion, that is to say, the muddy water. Experience has taught them that clear water is insufficient to produce good crops; also the basins supplied by feeders, whose heads are distant and which only carry water already clarified, are reputed less fertile than the others. A striking example of this kind was produced during the flood of 1885. The basin of Kocheicha, situated in the province of Beni-Souef, ordinarily received water which had lost almost all its sediment in passing through the upper basins, and the crops were not abundant. In 1885 the dike which separated it from the Nile was broken at the time the river was at its maximum height; the "red waters" thus rushed in and submerged it. The farmers obtained such good results upon the land which was subject to this inundation that they demanded and obtained that measures should be taken to introduce in the future the Nile water directly into their basins.

Inundation, besides the advantageous and fertilizing action exerted on the soil, contributes also to keeping it in good condition. By the pressure exerted on the surface of the ground the water

drives back the saline and hurtful solutions, which have a tendency to rise from the subsoil; in places where saline deposits have already been produced it serves to wash them away, dissolve them, and take them off with it.

The method of cultivation actually followed in the basins of Upper Egypt is without doubt that which was followed in the most remote ages; it consists of winter and spring cultivation. The winter crops are the true crops of the basins and the most extensive. Being made on land which has undergone inundation they do not need watering; however, in localities where submersion has been insufficient they fail if they can not be sustained by irrigation water.

In the basins a biennial cropping is generally practiced, comprising a crop of cereals, alternating with a crop of beans, lentils, or fodder. In the best situated lands, receiving abundant water, wheat can be cultivated for many successive years.

Sowing for winter crops takes place from fifteen days to a month after the recession of the water, about the beginning of November; the crops remain in the ground from four to six months, according to their nature; the soil then remains at rest until the end of the next flood, except in regions, generally quite rare, where spring crops are made by irrigation, as will be indicated below.

III. METHOD OF IRRIGATION.

All parts of Egypt have three kinds of crops: summer crops, and the crops of spring or autumn, and the winter crops.* The summer crops and winter crops are everywhere the most important; they remain the longest in the ground and occupy the largest extent of territory; but the spring and autumn crops, which require only from sixty to seventy days, are no less important to the country, for they are almost exclusively devoted to Indian corn and a kind of sorghum, called dourah, which serves particularly as food for the fellahs. Of all these crops, those which are made in winter on inundated lands of the basins of Upper Egypt are the only ones which do not require irrigation; all the others demand it more or less, according to their nature and the season during which they are matured.

The products of summer, which are for the most part sugar cane, cotton, rice, and Indian corn, are generally sown at the close of winter and harvested in autumn; they therefore require water during the hottest months of the year, which are exactly those during which the Nile is the lowest.

Summer crops can not be obtained in the interior of the inundation basins, these being submerged just at the time when they are in the ground. In Upper Egypt these crops are worked on high lands bordering the Nile, which are above ordinary floods, or at least easily protected from the high water; watering is here effected by means of elevating machines drawing from the river itself, from a depth which, during low water, is not less than 8 to 10 meters below the level of the soil; on some important estates, situated especially in the province of Esneh and Kenh, and provided with feeders by steam-pumps placed on the Nile banks; on the line of certain unimportant canals, dug at different points in the valley to bring the water of the low stage to a few lands back from the river; in the strip 5 or 6 kilometers wide and 200 kilometers long, extending through the provinces of Siout, Minieh, and Beni-Souef, which has been transformed into irrigation land by the recent construction of the great canal called the Ibrahimieh Canal; and finally in a large portion of Fayoum, a province which draws its water from the Ibrahimieh Canal.

Throughout Upper Egypt, except in these last two regions, the area susceptible of cultivation at the present time, in summer, probably does not exceed 40,000 hectares.

In Lower Egypt the summer crops are made wherever canals carry the water throughout the year, that is for almost the whole extent of the territory.

Generally, in Upper Egypt as well as in Lower Egypt, on well-managed estates, the summer crops occupy nearly a third of the cultivated area.

The winter crops, obtained by inundation, are, as in the inundation basins, the cereals, fodder plants, lentils, beans, etc.; these plants are sown after the waters of the flood brought to the land

* The summer crops are called in Egypt "sefi," winter crops "chetoui," spring and autumn crops "nabari" or "nili."

have caused a submersion of some days, and they are harvested in the spring; they grow then in the least hot period of the year; they need two or three waterings, and they are more easily raised than the summer crops.

In Upper Egypt these crops can be raised, outside the basins, upon the banks of the Nile; they are then watered, by means of elevating machines, like the summer crops, but with less expense, the level of the water being at this season of the year higher than in the hot season. They are raised also in all parts of Upper and Lower Egypt wherever there are irrigation canals which carry water during the winter months; that is, in the provinces watered by the Ibrahimieh Canal, in Fayoum, and some other localities of Upper Egypt, and over almost the whole area of Lower Egypt.

In the irrigable lands the winter crops cover usually two-thirds of the cultivated area.

As to the autumn or spring crops, which consist only of Indian corn and sorghum, they are sown generally at the time the flood comes to half its height, and they are harvested in sixty or eighty days afterward; their value not being large, advantage is taken of the epoch of high water in the Nile and canals, when irrigation can be applied most easily and with the least expense to water them; besides, as these crops are in the ground at the time of the year when the heat is greatest, they need frequent watering, which should in certain cases be repeated every eight or ten days; moreover, they are exhausting crops, which require fertilizers to develop.

These latter crops are the crops of rotation which can be made in Egypt wherever there is cultivation by irrigation. In practice they do not occupy more than a third of the irrigable soil; in many places the proportion of Indian corn and sorghum is much less. These products may also be obtained in the basins of irrigation themselves; they are sown here either along the feeder, at the time the canals begin to receive the Nile water directly or by infiltration, or at low points irrigated by means of infiltration water drawn from wells dug in the mud; here the crops should be cut and harvested before the basins are opened to the inundation water, lest they be injured or destroyed.

In Egypt, whether the water be taken direct from the Nile or brought by canals, there are many places that it does not reach, at least during a great part of the year, the level of the soil; the farmer is then obliged to raise it mechanically for watering.

On important estates they use for this work steam-pumps, but on small farms men or animals furnish the motive power. In the latter case, for small heights, the elevating machine (called "nattal")* consists of a kind of bucket of leather maneuvered by hand, by means of four cords, by two men; for heights a little greater the same kind of bucket is suspended by a rope to the extremity of a counterpoised lever, which turns about its point of support, this is the "chadouf,"† put in motion by a single man; for still greater heights several chadoufs are placed above each other, each taking the water from the reservoir to which it has been raised by the lower machine; the "noria" is also used, worked by means of an attachment to which an ox, a buffalo, or horse, or sometimes an ass or camel, is harnessed.

In the southern provinces of Upper Egypt no uniform system for aiding cultivation by irrigation has been adopted; the only important works which are found here are designed for inundation, and, except in rare cases, the proprietor or the peasant who wishes to water is obliged to obtain the water where the Nile naturally brings it and distribute it over his land by his own method. Only a few small canals for summer watering have been dug, and to mature the autumn crops in the basins a few inundation canals also have been deepened to a lower level than that which is strictly necessary to obtain submersion. It is not so in the north of Upper Egypt and in Lower Egypt, where important works of irrigation have been constructed in order to do away with the old inundation basins and carry direct to the cultivated lands situated away from the Nile a sufficient quantity of water for the summer crops during low water, and for the autumn and winter crops during the flood and mean stages.

In the north of Upper Egypt‡ irrigation is governed by a single great artery, the Ibrahimieh canal. This canal, constructed on the left bank of the river, has its head near Siout, and follows the Nile for a course of 260 kilometers; it is 100 meters wide at the mouth, and its bottom at this

* See Plate XVIII.

† See Plate XIX.

‡ See Plate III.

point is 2 meters below low water. The region irrigated by this great artery is about 6 kilometers in mean width; it is comprised between the Nile and a parallel dike which divides the valley throughout its whole length into two parts; the strip situated to the west of the dike is arranged in inundation basins. The Ibrahimieh canal serves for many purposes. It furnishes, by different branches, at all seasons, the water for that portion of the valley arranged for irrigation.

During the flood it furnishes to the Bahr Youssef, a great natural derivation, the water required to fill the basins situated to the west of the dike of separation.

By this same Bahr Youssef it carries all the year the water for irrigation into the province of Fayoum.

The construction of this canal is recent; it dates from the reign of the Khedive Ismail Pasha, that is, twenty years back; its principal object was to develop, in the provinces of Siout, Minieh, and Beni-Souef, the culture of sugar cane.

In Lower Egypt* the system of watering canals is far from being so simple, and if we glance at the map of the Delta we recognize with difficulty, at first sight, the principal lines of the complicated net-work which is there represented. To better understand the characteristic traits of the Delta irrigation, a little history is necessary and a return to the beginning of the century.

Before Mehemet Ali, seduced by the prospective wealth which would result to the country from the possibility of making on a grand scale summer crops, had constructed canals designed to carry to the very heart of Lower Egypt the water at the low stage of the Nile, this region was arranged for inundation basins; the water of the flood was then conducted to these basins by the two arms of the Nile, by a few secondary branches, and by wide but shallow canals. In a word, the system of submersion was practiced in Lower Egypt as it still exists in Upper Egypt; but since at many points of the Delta the water could not remain on the land more than from ten to twenty days, and very frequently at an insufficient depth, it was necessary to have recourse to additional irrigation to insure the preservation and growth of the crops. Therefore the country was, at this epoch, cut up by canals derived from the great canals of inundation and excavated, as these latter, to a depth sufficient to still have water two or even three months after the maximum of the flood. As in Upper Egypt, the feeders supplied series of basins separated from each other by dikes, which they passed successively, and beyond the last basin of the series they were prolonged by drainage canals, ending in the lakes in the north of the Delta. Each feeder ended thus in a drainage canal. When summer irrigation was desired, it was very natural to use for watering canals, as much as possible, the trunks of the principal canals of irrigation which then existed; it was sufficient for this to excavate the inlets to a depth of 1 to 1.5 meters below the level of low water, and towards the south of the Delta to a depth of 8 to 8.5 below the level of the soil. The slope given to these canals was less than that of the valley; their bottom, at a certain distance from the Nile, was not more than 3 or 4 meters below the soil; like ordinary canals for inundation, they were held in general at this level. As for the secondary branches of the old inundation canals, some of those nearest the Nile were deepened to receive the low water; others were left as they were, remaining dry during the summer, and finally the most distant were, almost without modification, supplied the entire year. Thus was created piecemeal, with elements of the primitive basins, a net-work designed for watering in the summer; perhaps even in certain cases it was possible to utilize for this new service works designed heretofore for inundation. During the flood all these same canals were employed for watering the autumn crops or for submersion, to slight depths, of lands intended to receive winter crops. As for the surplus water of irrigation and submersion thus brought to the land, it was not troublesome; its drainage was accomplished into the lower levels of the feeders, which were really drainage ways in the system of basins and were in fact so called in the country. Such are the general principles by which irrigation was substituted for inundation in Lower Egypt; they have led to the existence of a series of systems almost independent of each other and each comprising: †

A feeder canal having its inlet at the Nile, divided into many pools by works regularly disposed below the heads of the principal branches and holding water the entire year.

* See Plate IV.

† The deep canals fed throughout the year are called Sefi canals, the shallower canals which only have water during flood are called Nili canals, and the drainage canals go by the name of Masraf.

Secondary canals derived from the feeder, dug sufficiently deep to be supplied during low water.

Other secondary canals, not deep, which receive only the water of the flood; this secondary net-work tends to disappear more and more by being transformed into deep canals.

A general drainage canal, which is nothing but the lower extremity of the feeder, terminating at the lakes in the north of the Delta, but which receives little more than the surplus of the canal itself; because, most frequently, there are no drains to collect and carry to it the discharge water of the lands. These canals of irrigation have generally a slope of from .04 to .05 meters per kilometer.

During low water they discharge the water at a much lower level than that of the land; except however, in the regions remote from their inlets from the Nile; the slope of these canals is more gentle than that of the valley. During flood they deliver their water almost for their whole length at the same level as the cultivated land.

This whole collection of canals is very far from having assumed its state of equilibrium and its definitive position; it presents in fact many defective points, not only in details but even in the principal disposition, and engineers in endeavoring to remedy these inconveniences make continual changes in the canals themselves and in the regimen of their water.

Many causes have contributed to retard the rational progress of irrigation in this country. They are principally the lack of patience and perseverance in the execution of the work, the imagination and zeal of the contractors who urged the Government to begin works always enormous, and to leave them unfinished to pass to others, the rapidity with which an absolute power exacts that a work hardly conceived should be executed, and the disdain of the operations and details destined to give this work all its value. To the same effect is the facility with which manual labor, furnished gratuitously by an army of laborers, permits the execution of works of canalization in a country entirely level and in a soil composed wholly of mud, a facility valuable but whose consequence in Egypt has been the hasty execution of works badly elaborated and often too considerable for their object, sometimes useless and causing detriment to the unity of the system. There is also the action of the large proprietors, turning to their own profit and to the detriment of the small farmer the benefits of irrigation, causing by personal and selfish combinations confusion in the feeders of the net work of canals and the distribution of the water. There is again the spirit of routine of the population, as well as the frequent inexperience and want of originality of the Egyptian engineers charged with the regulation and regimen of the canals. It is finally meagerness and want of regularity of official resources appropriated for irrigation, and the lack of maintenance which thereby results, and which prevents, for example, the dams echeloned along the canals, and become useless, from performing the duty for which they were constructed. All these defects are tending slowly to disappear, and for some years the regulation of the canals of Lower Egypt has been very notably improved in these different particulars. The attention of engineers is now given to two improvements whose realization will be of the greatest importance: First, the establishment in the canals of a fixed level, such that irrigation may be afforded everywhere without the aid of elevating-machines; and, second, the construction of drains. The first result will be obtained generally, either by means of dams or by proper regulation or by combining the canals in such a way as only to water, with each of them, the lands remote from their inlets; as to the question of disposal of the drainage water, it is a very complicated one to solve.

In the highest lands, those situated toward the point of the Delta or on the banks of the Nile arms, the only water to be carried off is that which comes from the drainage of the irrigated lands, and it demands little attention, the drying of the ground effecting it by infiltration into the subsoil. There will be doubtless some drainage undertaken later, but the need of it is not yet felt in these regions. On the contrary, in the lands lower and more remote from the river, the lack of drains produces hurtful effects on the crops and transforms vast spaces into marshes. This notably occurs in the vicinity of the lakes in the north of Lower Egypt, where the land, little elevated above the sea level and having a weak slope, receives not only the overflow of the canals of irrigation, but also, through the subsoil, all the drainage water of the high lands. In the present state of affairs the drainage of this water is accomplished with difficulty: first, because there is in these regions a lamentable confusion between the canals of irrigation and the drainage canals which form their pro-

longation, and in which the riparian owners seek to retain water for moistening the land; secondly, because the irrigation canals, having in general their bottoms at a level lower by 3 or 4 meters than that of the land, carry towards the sea uselessly the whole mass of water lower than the soil, and fill the drainage canals with it, at least for a part of the year, to a level higher than the neighboring land. It is evidently only possible to obtain a good result by limiting to the strict needs of cultivation the quantity of water thrown into the irrigation canal by separating very thoroughly, in the low regions, the drainage canals from the watering canals and by creating entirely a special net-work of drying trenches. This is being worked at this time, but a difficulty of another nature is met with. All this drainage water can only in fact be discharged into the lakes which border the sea. Now, these lakes have a very variable level; during the flood the enormous quantity of water which comes to them, either by the arms of the river or the great canals, empties itself but slowly by the narrow mouths which form the communication between the lakes and the sea, and therefore the height is much increased; besides, the action alone of the prevailing winds suffices to raise their level more than a meter. Under these circumstances the riparian lands, situated less than a meter above the sea-level, can only be regularly cultivated by diking or modifying the regimen of the lakes, so as to give them less water during the flood. Some attempts to better these low lands have already been made, but they were very few and of too late a date to be interesting to speak of.

Such are the most notable peculiarities which irrigation presents in Lower Egypt. As to the arrangements of the great canals which water this region and their mode of supply, a few words will suffice to give a general idea. At the very point of the Delta* is built the well-known great dam, with movable gates, which extends across the two arms of Rosetta and Damietta, distant from each other at this point about 1 kilometer. This work, whose construction began about 1843 and which is not yet finished, has for its object the creation of a pool in the Nile 4.50 meters in height and the distribution of all the water necessary for Lower Egypt by three great canals, having their inlets in the pool above, one to the west of Rosetta arm, another for the Delta proper, comprised between the two arms of the Nile, and a third for the lands situated to the east of the Damietta arm. The canal of the center and that of the west exist, but the canal of the east is not yet constructed; moreover, on account of the unfinished condition of the dam itself, there has only been obtained to the present day a maximum level of 3 meters on the Rosetta arm and 1.6 meters on the Damietta; it is intended to finish and strengthen this work so as to have it support a pressure of 4 meters of water. Under these circumstances the irrigation of eastern Lower Egypt is assured for the present by a series of canals arranged along the right bank of the Damietta arm, to the north of Cairo above and below the dam; the provinces of the center receive their water from the canal of the center, or Rayah Menoufieh, which has its inlet above the dam, and by several canals whose mouths are grouped upon the Damietta arm in the first 40 kilometers below the same work; finally the provinces of the west are watered in part by the western canal or Rayah Behera, which has its inlet above the dam, and in part by two great canals, the Katatbeh and Mahmoudieh, situated below, and into which the water, in time of low water, is elevated from the Nile by powerful machines. To the discharge of all these canals is added the product of numerous steam-pumps specially established on the banks of the arm of the Nile.

Since during the period of lowest water the summer crops are the only ones which are in the ground, and as the autumn and winter crops are not yet begun, the wants of the summer crops determine the minimum supply of the canals; but opinions have varied much in Egypt, since irrigation has been carried on, as to the quantity of water which it is necessary to give the crops.

Originally the farmers, on account of the large revenue which the products of summer afforded, had a tendency to irrigate more land than the discharge of the canals could supply; but they quickly saw that the soil was giving out by this method and that the crops diminished; therefore they were brought to gradually increase the volume of water per hectare, and consequently to reduce the area cultivated in summer.

The international commission which was appointed to study the Suez Canal was consulted by the Khedive to determine the quantity of water necessary for irrigation in Egypt; it concluded from

*See Plate IV.

study that there was needed a constant discharge of 55 centiliters per second per hectare. Linant de Bellefonds indicates in his works also, as a quantity acknowledged sufficient for ordinary purposes, 65 centiliters for the rice fields and 44 centiliters for other crops, being a mean of 55 centiliters. The same author declares in another place that 826 millimeters are hardly sufficient for cotton and sugar-cane, and 989 for the rice fields.

Mr. Fowler, the engineer, who studied in 1875 the projects for the entire irrigation of Egypt, based all his calculations upon a mean of 193 millimeters per second and per cultivable hectare. Admitting, as is generally the case, that on well-regulated estates a third of the land should receive summer crops, this discharge would correspond to 58 centiliters per hectare of crop.

The ministry of public works, in projects for irrigation by elevating-machines, regarded as sufficient a constant flow of 65 centiliters per second and per hectare. For rice fields, also, they considered this amount sufficient.

At present, in the projects which are being executed or studied, it is admitted that a supply of 826 millimeters per second and per hectare of summer crops gives a sufficient irrigation during low water, and that for the rice fields a little more is needed. It is estimated also that these 826 millimeters per hectare, applied to a third of the cultivable surface of a region, suffices largely for the needs of this region, and it is this amount of 0.825 liters divided by 3 = 0.275 liters per second and per hectare which serves as a basis for calculating the low-water discharge in the canals. This is the amount which should be given the canals at their inlets, making allowances for all losses from evaporation or infiltration.

But as soon as the water of the Nile begins to rise it is necessary to provide for a much greater distribution of water; it is, in fact, at this epoch that the lands designed to receive the autumn crops are watered, while still reserving all the water necessary for the summer crops. According to the custom of the country, Indian corn or sorghum is sown throughout the whole of Lower Egypt during a period which does not exceed fifteen to twenty days; during this period it is estimated that the quantity of water spread over a certain region should be five times that which is furnished during low water, but generally it is confined to less quantities. Then comes the preparation of the lands for the winter crops, which consists of a submersion of some centimeters and a washing of the soil; but the requirements are not so great and less urgent in the month of August, during the rising of the flood.

Upon the whole, if we compare the quantity of water recognized as necessary for irrigation in Egypt with that in other countries, we see that it is not very high.

In India, for regions cultivated under almost the same conditions as in Lower Egypt, they estimate from 22 to 28 centiliters per hectare of cultivated area; and in the province of Bengal it is estimated that a continuous supply of 874 milliliters per cultivated hectare is sufficient. In Egypt the calculated amount is 826 milliliters only.

In Lombardy they estimate for the natural meadows one liter per second per hectare; for rice fields, 2.50 liters; for the other crops, 6 deciliters, being a mean of 1 liter per second and per hectare for a quite extensive region. In the south of Spain the supply varies from 75 centiliters to 1 liter for ordinary crops, and goes as high as 2.48 liters for the rice fields.

Finally, in the south of France it is estimated that a continuous discharge of 75 centiliters gives a sufficient irrigation, but when possible the basis of calculation is 1 liter per second and per hectare.

The supply accepted in Egypt, then, is generally less than that adopted in other countries even less arid.

If we consider the most extensive crop of Lower Egypt, that of cotton, which during the five or six months which it remains in the ground requires about ten wettings, we find that the normal supply of 826 milliliters per second and per cultivated hectare corresponds to a total supply of 10,700 cubic meters for the cultivation of a hectare of cotton. This quantity is less than that of 14,000 cubic meters which is let into the basins of inundation for the culture of 1 hectare. Moreover, as the wettings are made especially during low water, that is to say, at the time the water is least charged with mud, and hardly contains one-twentieth of that contained at flood, it results that irrigation is far from carrying to the land the same fertilizing principles as inundation; it

may be truly said, however, that by wetting, all the particles of water enter into more intimate contact with the soil than by submersion.

The total area at present capable of cultivation in Lower Egypt as well as Upper Egypt being 1,320,000 hectares, the quantity of water needed during low water for all the crops would be 1,320,000 multiplied by 0.275 or 363 cubic meters per second, which represents a considerable portion of the discharge of the Nile at this time of the year. But there has not, up to the present, been so much water devoted to irrigation in Egypt.

About 1860 Linant de Bellefonds calculated that the discharge of all the canals at mean stage was 62 cubic meters per second; adding to this the water of the elevating machines we have, for this epoch, 80 cubic meters, more or less, per second. Up to 1882, the discharge of the canals, at low water, increased by the water of the elevators, hardly exceeded the total of 275 cubic meters per second at the maximum, and finally, in 1885, thanks to the pool of 3 meters height made by the dam at the apex of the Delta, the quantity of irrigation water amounted to almost 300 cubic meters per second. Unfortunately, in the present state of affairs, the greater part of this water taken from the Nile is still lost to cultivation, and flows uselessly to the sea on account of the imperfections of the regimen and system of canals.

According to Nadault de Buffon, the total quantity of water employed for irrigation in Lombardy, about 1860, was 380 cubic meters per second, a volume a little greater than that which is required in Egypt during low water; it is true that, owing to the essentially different mode of cultivation in the two countries, these 380 cubic meters are applied to a cultivated area about a third less than in Egypt; all the land in Lombardy requires water at the same time during summer, while only a third of the Delta is cultivated at this season.

If we wish to apply irrigation to the whole of Egypt and to do away entirely with basins, the total cultivated area being 2,000,000 hectares, there would be needed during the summer a supply of 550 cubic meters per second, which often exceeds the discharge of the Nile at low water. It is evident, then, that it is not possible to increase indefinitely summer culture in Egypt, unless we change the regimen of the Nile by creating pools and immense reservoirs which would store the flood water in order to return it during low water.

CHAPTER III.

DESCRIPTION OF THE DIFFERENT IRRIGATION WORKS OF UPPER EGYPT.

DIKES OF THE NILE AND WORKS OF PROTECTION AGAINST OVERFLOW—INUNDATION BASINS OF THE REGION OF THE SOHAGIEH—IBRAHIMIEH CANAL AND THE PROVINCE OF FAYOUM.

A complete description of irrigation in Egypt should comprise the detailed description of the system of watering in each province; but this would be a wearisome labor and without much importance. Short references to some of the most interesting works and canals will serve better to point out what is the present condition of irrigation in this country.

I. DIKES OF THE NILE AND WORKS OF PROTECTION AGAINST OVERFLOW.

The great bed of the Nile is limited throughout its entire course by dikes whose crests are raised above the level of the highest flood. When one of these dikes becomes broken by the pressure of the water great havoc may result, because in general the level of the flood much exceeds that of the riparian lands, and especially in certain parts of the Delta the high water reaches normally 2 meters above the soil of the valley. Therefore the Egyptians pay the greatest attention to the maintenance of these works in good order. In Egypt, where the country is almost absolutely flat, a dike can only be constructed by taking the material all along its line from borrow pits, whose junction form a kind of lateral canal at the very foot of the dike. The following is the method of constructing the Nile dikes with the mud of the valley obtained at their base; they are located at very variable distances from the river, and are not constructed to follow it through all its detours, so that the land comprised in the greater bed thus bounded is often cultivable even during ordinary floods; it is very difficult to-day to give the local causes which have led to the adoption of one position more than another for these dikes; the cause is doubtless the numerous changes which the Nile has undergone since the construction of these works.

The profile of the dikes is generally quite irregular; the type profile adopted is 4 meters wide at the crown with a height of 1 meter above the level of the highest floods and slopes of one vertical to three base. All the Nile dikes conform more or less to this type profile.

When the riparian owners along the river desire to raise the water by means of elevating-machines for the irrigation of their lands, they are allowed to build through the dikes, aqueducts or culverts. These openings, although they are closed and guarded in time of floods, are nevertheless a threat to the safety of the country, they are, however, rarely the cause of rupture of the dikes. On the score of prudence, such authority should not be granted at points where the flood rises more than 1.50 meters above the soil on which the dike on the river bank rests, nor where the distance between the foot of the dike and the bank proper of the Nile is less than 50 meters.

The dikes being constructed of earth and their base resting simply on the mud, it is necessary to employ special methods to protect them against the action of the high water. The effects of the river on the banks are produced generally in two ways, either the current impinges with violence against the threatened point, or the water, passing with its maximum velocity at a short distance from the bank of irregular contour, creates along the bank counter currents and eddies, which rapidly carry away considerable portions of the riparian property.

It is very difficult, in certain cases, to counteract effectively this caving, since the water at medium stage, which occupies a bed much narrower than the flood, produces an effect opposed to that of the flood, filling where it has excavated, and excavating, on the contrary, where the flood made deposits.

A few years ago people confined themselves to strengthening the slope of the banks, wherever attacked, by means of stone thrown in without plan; much stone was thus expended without great results. Now there has been adopted a system of dry stone spurs, designed to fix the direction of the current, trees, branches and cages filled with stone, which are arranged along the bank, in front of which it is desired to induce deposits of sediment. They have already succeeded in giving to the larger bed of the river a greater stability.

There are annually expended nearly 100,000 cubic meters of stone in revetment or spurs along the Nile throughout the whole of Egypt.

II. INUNDATION BASINS OF THE REGION OF THE SOHAGIEH CANAL.

It has been shown that the system of irrigation by basins consists of:

Canals for carrying the water.

Longitudinal and transverse dikes which inclose the basins.

Works established in these dikes for receiving and draining off the water.

Works and canals of discharge into the Nile.

The series of basins fed by the Sohagieh upon the west bank of the Nile, to the north of the province of Guirgah and to the south of the province of Siout, may be taken as a type of this system.*

The feeder canal is formed by an ancient water-course, called the Sohagieh, whose inlet is on the Nile, just above the city of Sohag, and which traverses, following the whole slope of the valley, the series of basins which it supplies for a length of 150 kilometers.

The Sohagieh loses itself at the lower extremity in the Bahr Youssef, another natural water-course, which forms, so to speak, its prolongation. A large inlet work is established at the head of the canal. It comprises 214 arches of 3 meters span, and has very much the character of the irrigation works established in this country at the beginning of the present century, which have almost all forms too strong for the pressure to which they are subjected, with enormous abutments and exaggerated openings for the discharge which they were required to furnish.

As with most works constructed in the Nile valley, the foundation rests on mud plentifully mixed with sand, and also gravel when depths 8 to 10 meters below the level of the soil are reached, that is to say, upon earth highly subject to scour and slightly compressible. The foundation bed is 40 meters long and 2 meters thick throughout. It is of beton revetted with two layers of brick placed upon the earth. This is the method of construction most generally employed for the foundation beds of such works. Stone work in ashlar forms the rear foundation below and protects the mass of masonry from undermining. The superstructure of the work is of brick, except the corners, faces, rabbets, etc., which are of cut stone.

The piers are 2 meters thick; their total height is 5.69 meters from the level of the foundation bed to the springing line of the arches. Also the top of the piers on the up-stream side are 10 centimeters above the level of the highest flood. The surface of the foundation bed is placed at 3.50 meters above the lowest water. The bed of the canal is then dry during mean low water and while the river is below this level.

To regulate the discharge of the Sohagieh and close it, either before or after filling the basins, grooves 30 centimeters wide are arranged in the faces of the piers, which permit the arches to be closed by means of shutters 25 centimeters thick. The maneuvering of the shutters is very difficult, for they are heavy and it is often necessary to raise them under a pressure of from 4 to 5 meters of water. They use for this purpose a car furnished with winches, which is moved along the bridge by traveling on rails laid on longitudinals which rest on the starlings of the piers.*

In 1885 the inlet work of the Sohagieh was opened August 10 and closed October 1.

This work, as well as all the hydraulic work in Egypt, is built with mortar formed of a mixture of fat lime and brick-dust.

* See Plate II.

† See Plate V.

The dikes of the basins are constructed entirely of mud; the cross-section is, as with the Nile dikes, quite irregular. The slopes are generally 2 base to 1 vertical, but the type profile adopted has slopes of 3 base to 1 vertical with 4 meters thickness at the crown; all the dikes are generally coming to this type.

The slopes of 3 to 1 are maintained perfectly and give sufficient solidity to the embankments, which are often, in the low parts of the basins, 5 to 6 meters in height. Besides, the north winds, which blow continuously during the season of inundation, form the surface of the water into waves which erode the north slopes of the dikes; they are now protected, to prevent rupture, by mats of reeds, which lessen the effect of the waves. In spite of these precautions it is necessary each year, before the flood, to repair these slopes.

The dikes describe, in their plans, many zigzags; doubtless they were originally nearly rectilinear, and built on the boundaries of the low lands of the different villages, but at the points of accidental rupture, or of cuts made for drawing off the water, it has been necessary to reconstruct them, to make detours, up-stream, around the deep holes dug by the current caused by the breaks. There has resulted, all along the general direction of the dikes, numerous elbows, whose cause at first sight are not evident. In the upper part of its course the bed of the Sohagieh canal is separated from the basins, which border it, by longitudinal dikes, whose crest is horizontal, all along the same basin, in order to permit them to retain the water; the canal feeds each of the basins by an interval left between the upper end of its longitudinal dikes and the lower transverse dike of the basin above, without the necessity of establishing dams on the canal itself. Many of these basins inundate, by means of bridge dams, others of less importance which do not receive the water direct from the canal. Finally, a few small basins are still filled, at least in part, by secondary canals having a direct inlet from the Nile. These last are those whose level is the highest in the transverse profile of the valley.

In the lower part of its course the Sohagieh is no longer diked; its bed simply crosses the transverse dikes of the basins by means of bridge dams, which permit the maintenance of a suitable level in each of the successive reservoirs; in these basins the bed proper of the canal is simply the lower portion of the land, and its greater bed is bounded on the west by the mountains of the Libyan chain, and on the east by the Nile dikes.

The basins thus laid out on the surface of the valley are often of very different dimensions, as the following table, which comprises all the basins supplied by the Sohagieh, shows:

Basins.*	System of supply.	Area. <i>Hectares.</i>
West of Sohagieh	By the Sohagieh diked along the basin	21, 689
North of Sohagieh.....	By the Sohagieh and secondary canals.....	4, 200
Samarra.....	By the basin above	4, 894
Benawit	do	4, 216
Enebis	do	4, 248
Sahel	By the basin above and secondary canal.....	1, 695
Kom Badr	By the Sohagieh diked along both banks and crossing the basin....	3, 375
Banaho	By the basin above	771
Banga	do	1, 323
Ondomah	By the Sohagieh, which crosses it diked on both banks.....	5, 902
Madmar	By the basin above and secondary canals	2, 040
Sahel	do	1, 624
Douer	By the basin above	4, 238
Beni Smia	By the Sohagieh, which crosses the basin without dikes	15, 038
Zerah	do	16, 512
Meera	do	3, 424
El Kelbi.....	do	8, 831
Beni Rafa	do	5, 334
Maharra.....	do	6, 237
Kossieh.....	do	5, 198
Dalgaoin.....	do	19, 254
Total	139, 622

* See Plates II and III.

The map of the basins of the Sohagieh, comprised between Sohag and Siout, indicates also the components of the system of basins on the right bank of the valley, a system cut up by many rocky promontories, which on this side advance even to the bed of the river.

The same map shows that the villages are built in the interior of the basins; in order to avoid inundation these centers of population are established on artificial mounds raised to the height at least of the dikes.

The communication between the different basins, as well for filling as for emptying, is accomplished generally by means of masonry works, which are composed of arches of 3-meter span, closed by means of shutters, and which, although less important, are disposed almost similarly to the inlet bridge of Sohagieh.* As these works are not always sufficient to discharge the requisite volume of water at the desired moment; it is usual to make breaks in the dikes. This latter method, which is costly, since it necessitates each year the establishment of heavy earthwork, will disappear in proportion as the number of regulating works are increased. Often to avoid the difficulty of placing and raising the horizontal shutters, with depths of water which may be as much as 5 or 6 meters and with a great resultant pressure, horizontal beams are placed permanently across the arches, at intervals of 1 to 1.50 meters, supported at their extremity in the grooves of the arches; the closing of the work is then accomplished by means of vertical timbers, which are supported below by the sill of the foundation, and at intermediate points by the fixed transverse beams. But this method forms with difficulty tight fermeture, and many of the timbers are broken in handling them, which is done by means of winches and cranes placed on the top of the bridge. It can not be said, up to the present, that there is in Egypt a very complete or well-considered system of fermeture for all these works.

There have not yet been constructed, although they have been planned for a long time, specially important works for emptying the basins into the Nile, and a barbarous method is employed, which consists in cutting a portion of the dike along the river and allowing the water to escape through this breach. All the basins between Sohag and Siout are discharged for the most part by cuts made every year in the dike between Aboutig and Siout.

As to the basins situated to the north of Siout, they empty themselves into the Bahr Youssef, which itself with the whole series of basins along the Ibrahimieh canal, of which mention has already been made in the preceding chapter, empties into the Nile by a breach made in the dike of the Kocheicha basin to the north of the province of Beni-Souef and by another breach made in the Racca basin, situated below the preceding.

As the emptying of the basins is done most frequently at the time when the Nile is still high, it is necessary to be careful to regulate the time of the different discharges and their intensity, so as not to produce a supplementary flood too liable to submerge a portion of the crops situated below. Thus, in certain years the breach in the Kocheicha dike having been opened suddenly, the water rose at Cairo more than 1.50 meters in twenty-eight hours. This is an accident to be avoided. A great exceptional flood was produced in 1878 because, the water having continued to rise for a long time, it was necessary to empty the basins at the time that the Nile at Assouan was not yet falling. This flood was thus a disaster for several provinces.

In 1885, when the return of the inundation water was made under good conditions, the discharge of the basins of Upper Egypt were so regulated that it extended regularly over the first twenty days of the month of October.

The maintenance of the works necessary to manage the basins comprises principally the rebuilding and repair of the profile of the dikes after each flood, refilling the breaches made for the discharge of the water, and the cleaning of the canals, in which deposits of mud are principally formed near their mouths. These works of repair, which consist consequently of earth-work, are quite considerable. Up to 1883 they were executed exclusively by the corvée, but since that time they have been let partly to contractors.

In the province of Guirgneh, which incloses 137,000 cultivated hectares, the mean annual volume of earth-work which was heretofore executed by the corvée, from the official accounts rendered to the ministry of public works, was 3,500,000 cubic meters, half upon the dikes and half

* See Plate VI, the type of these works.

in the canals. This makes 26 cubic meters of earth-work per cultivated hectare. The total expenditure in connection with these works, supposing them done entirely by contract, is now estimated for the service of irrigation at 1,170,000 francs yearly, being 8 francs 65 centimes per hectare under cultivation.

In the province of Keneh, which contains 118,000 cultivated hectares, the mean yearly amount of earth moved by the corvee was 3,800,000 cubic meters, of which 1,450,000 cubic meters were in dikes and 1,350,000 were in the canals. This gives 12 cubic meters per hectare for dikes and 20 cubic meters for the canals, in all 32 cubic meters.

The cost of the work of maintenance in this province, if done by contract, is now estimated at 1,140,000 francs, or 9 francs 50 centimes per hectare.

In the province of Esneh, which is of much less extent and which only includes 63,000 hectares, the annual volume of earth-work is 900,000 cubic meters, 350,000 on the dikes and 550,000 in the canals, which gives per hectare 5.50 cubic meters for the dikes and 8.70 cubic meters in the canals; in all, 14.30 cubic meters.

From present estimates the repairs of the canals in this province will be done by contract for 535,000 francs, or 8 francs 50 centimes per hectare.

In the three provinces of Esneh, Keneh, and Guirgneh, which are the only provinces in which there are no special great canals for summer watering, and which have an area of 318,000 hectares cultivated, the total volume of earth annually moved was, a few years ago, 3,550,000 cubic meters on the dikes and 4,650,000 cubic meters in the canals; in all, 8,200,000 cubic meters; and the annual expenditure for executing all this work by contract is estimated to-day at 2,845,000 francs.

These reported amounts, to the hectare of cultivated land, correspond to an average movement of 11.16 cubic meters on the dikes and 14.62 cubic meters in the canals, or 25.78 cubic meters in all per hectare, and the annual expenditure is a mean of 9 francs per hectare.

As the canals of the basins only receive water during low water, all this earth-work is executed dry.

III. IBRAHIMIEH CANAL AND THE PROVINCE OF FAYOUM.

The Ibrahimieh canal has its inlet near the city of Siout. By itself and branches it serves to submerge or irrigate all or a great part of the province of Siout and all the crops on the left bank of the Nile in the provinces of Minieh, Beni-Souef, and the whole of Fayoum, which represent an area as follows:

	Hectares.
Part of the province of Siout.....	75,000
Provinces:	
Of Minieh (left bank).....	165,000
Of Beni-Souef (left bank).....	93,000
Fayoum.....	97,000
Total	430,000

Of this amount 240,000 hectares are arranged as basins of inundation, and it is not advisable here to make summer watering, as the water reserved for the more favored lands, which are devoted to the cultivation of sugar-cane, can not be used for this purpose.

The Ibrahimieh canal* is composed of two very distinct sections. The first is 61 kilometers long. This is only in reality a feeder canal, which is not utilized for watering the riparian lands; they are too high above the level of low water.

At the sixty-first kilometer this feeder is divided into many branches.

The Ibrahimieh canal, a direct prolongation of the common trunk, designed to carry the water of irrigation, and which is 195 kilometers long.

The canals of Sahelieh and Deroutieh, which flow, the first between the Ibrahimieh canal and the Nile, the second to the west of the Ibrahimieh canal, and which are specially reserved for the irrigation of lands nearer the point of bifurcation.

The Bahr Youssef. This canal, or rather this water-course, serves to carry the water of the low stage as far as Fayoum, and during the flood to fill the series of basins of inundation arranged to the west of the belt of land which is reserved along the Nile for irrigation.

* See Plate III.

The first portion of the Ibrahimieh canal, or the feeder, has its mouth a short distance north of the city of Siout and extends as far as Derout. The canal at first describes a curve, directing itself towards the north, then it follows very nearly the course of the Nile. In this locality the lands situated on the left bank of the canal are cultivated by inundation and receive their water from the basins above. As to the lands, of little extent, which are situated between the canal and the river, they are cultivated by irrigation, by means of elevating-machines drawing from the Nile or from the secondary canals.

● The Ibrahimieh canal has no inlet work from the Nile: the water of the river enters it freely. The banks dug in the mud are simply strengthened by means of riprap reaching back from the mouth for about a kilometer in length, that is to say, to the point where the canal is crossed by the railroad from Siout to Cairo.

The normal width of the bottom at the mouth is fixed at 35 meters, and the slopes at 2 base to 1 vertical; but the canal, in this level, being a true river with a rapid current, it is difficult to preserve for it between its muddy banks a very stable profile. The width also varies, at the bottom from 50 to 70 meters, and at the level of the soil it is comprised between 90 and 120 meters. The limit of 35 meters indicated above is then at present purely theoretical. The canal having its mouth free, the level of the bed at the inlet varies continually, according to the deposits brought by the water. They always endeavor to maintain during low water by dredging this level at the 42.65 meter mark, or at a depth of 2 meters below the level of low water for the normal width of 35 meters. The level of the cultivated lands at this place is the 51.80 meter mark. The bottom of the canal is therefore found to be 9.15 meters at low water, 7.15 meters below the soil of the valley. The slope of the canal being less than that of the valley, the level of low water gradually approaches the cultivated lands and very soon reaches it in the secondary canals.

The maximum high-water mark at the mouth of the Ibrahimieh canal is 53 meters, or more than 8 meters above the level of low water and 10 meters above the bottom of the canal; the dikes have a command of 1 meter at least above the highest water.

The railroad bridge, which crosses the canal 1 kilometer below its mouth, is composed of a draw span of 30 meters, supported at its middle point by a masonry pier 6 meters wide, and three iron spans, each having a clear opening between piers of 18 meters. The lowest point of the roadway is 11 meters above the level of the lowest water.

The mean slope of the canal in the first 61 kilometers, between Siout and Derout, is 45 millimeters per kilometer.

Under the conditions indicated above the canal takes, in low water, 50 cubic meters per second, or more than one-tenth the total discharge of the Nile at ordinary low water; at high water it takes 740 cubic meters per second.

The discharge of the Ibrahimieh is never well assured in low water, because it depends both on the height of low water and the level of its bottom obtained by dredging, in fact it is not alone the deposits of mud which fill this canal, but, especially at its mouth, even at low water, the sand and heavy matters are drifted along the bottom and tend to raise it at the time that watering is most necessary for the crops. Thus, notably in 1882 and 1883, a bank of sand, which was deposited along the bed of the river in front of the mouth of the Ibrahimieh, sent to the canal deposits in such quantity that four powerful dredges could hardly make headway against the choking up which resulted.

The volume dredged on the 61 kilometers between Siout and Derout in the last four years is as follows:

	Cubic meters.
1882.....	636,744
1883.....	716,195
1884.....	818,430
1885.....	634,269

At Derout (kilometer 61) begins the distribution of the water of the Ibrahimieh canal. At this point the canal widens into a kind of basin, along which are constructed six works of distribution; they are:

First. Upon the right bank, a reservoir to carry back to the Nile the surplus water of the principal trunk. This work consists of five openings of 3 meters; a lock 8.50 meters wide and 34

meters long between miter-sills is here built, and affords, during high water, communication between the Nile and the Ibrahimieh by the return canal.

Second. On the right bank, a little below the reservoir, the inlet of the Sahlieh canal, composed of two arches with openings 3 meters wide.

Third. In the axis of the basin, the distribution work built for the Ibrahimieh canal itself; it consists of seven arches of 3-meter openings, with lock 8.50 meters wide for navigation.

Fourth. On the left bank of the canal, the water inlet of Deroutieh, composed of three arches of 3 meters.

Fifth. Again, on the left bank, the inlet of the Bahr Youssef, comprising 5 arches of 3 meters and a lock 8.50 meters wide for navigation.

Sixth. Finally, on the same side, an inlet of two arches of 3 meters, for filling several basins situated on the left bank of the Bahr Youssef, and at a level too high to be filled by the Bahr Youssef itself.

All these works are closed by means of horizontal stop-planks.

The principal ramifications of the Ibrahimieh canal are, then, the two great navigable arteries which are the prolongation of the Ibrahimieh itself, the Bahr Youssef and the two secondary canals, viz., the Sahelieh and the Deroutieh. The sills of the inlets of these different canals are at different levels; the highest are those of Deroutieh and Sahelieh. These sills have been established for a regimen of distribution different from that adopted at present; they are in general below the level adopted for the canals themselves, a level very variable and which, on account of large deposits of mud, depends entirely upon the depth of the yearly dredging.

At present the 39.90 meter mark above the sea level is fixed for the bottom of the principal trunk at Derout, or about 5.50 meters below the level of the soil. The level of low water is therefore 3.50 meters below the land, the slope of the surface being considered the same as the slope of the bed, that is, supposing the level is not affected by the regulating works. As to floods, the flow is regulated so that it will not exceed at this point the level of the crown of the works, fixed at 47.515 meters, or 7.60 above the bottom.

Sahelieh canal.—The Sahelieh canal, which has a width of 8 meters at the bottom, at its mouth is kept at a depth of 4 meters below the level of the soil, or 1.50 meters above the bed of the Ibrahimieh. It trends between the Nile dikes and the Ibrahimieh canal for a length of about 40 kilometers as far as Abou Kourkas, using most frequently the bed of the ancient canals. Various works for holding the water are arranged along its course. The first kilometers of the canal are costly to maintain on account of the mud deposited annually, and because the products of dredging dumped each year on the banks render the work more and more difficult. This earth-work is done dry; it amounts annually to a mean of 90,000 cubic meters.

Deroutieh canal.—The Deroutieh canal, constructed entirely anew at the same time as Ibrahimieh, has a regular course. The width at the bottom is 10 meters at its inlet at Derout: its level is the same as the Sahelieh.

The normal slope of the bed is 65 millimeters per kilometer.

The length of the canal is 70 kilometers, and the cross-section diminishes in proportion to its distance from the inlet.

The cross-section is quite irregular in consequence of defective dredging, which has been done by the men of the *corvée*. At certain points the distance between dikes varies from 30 to 40 meters. It is therefore difficult to specify at present a typical cross-section for this canal.

During low water the discharge can be increased to 7.56 cubic meters per second by completely opening the dam at the inlet. There are necessary for agriculture about 4 cubic meters.

During high water the canal should discharge about 28 cubic meters per second. This discharge is necessary on the one hand for the winter crops of the region between the Ibrahimieh and the chain of the basins on the west, and on the other hand to complete the filling of the basins of Achmounin and Tanachaoui, representing 32,000 hectares of surface, which, as we will see farther on, can not be completely filled by the Bahr Youssef. This partial inundation is made by simple breaches cut in the west bank of the canal.

At about the thirty-third kilometer the Deroutieh canal can receive, in case of need, the water from a branch of the Ibrahimieh, an ancient canal bed, capable of supplying to the thirty-

eighth kilometer, which terminates the Deroutieh, the water needed to irrigate the whole territory between the Ibrahimieh and the basins as far as Minieh.

This communication, established by the Sabaka between the Deroutieh and the Ibrahimieh canal, presents another advantage. The necessity of introducing in great quantities the muddy water into the bed of the Deroutieh for the partial filling of the basins causes, for the first 10 kilometers, considerable deposit. To remove these deposits it is necessary to drain the bed dry, beginning at the outlet. The Sabaka canal during this time furnishes the water needed for the summer crops, and this quite conveniently, because at the first kilometers the irrigable area is not extensive, the Ibrahimieh canal being very close to the longitudinal dikes of the inundation basins.

When the work of clearing out the Deroutieh was performed by the *corvée* it was done twice; the first time in the month of March, before the planting of the sugar cane needed the water, and the second time at the end of May, a little before low water, in order that the young plants should not be deprived of water before the flood.

At present this work is done by contract. It is possible with the new arrangements for the distribution of water to shut the upper part of the canal during the months of October, November, December, and January while there is less need of irrigation, and thus allow the contractors all the time required to perform their work dry; it amounts to 120,000 meters.

Prolongation of the Ibrahimieh canal.—From the point of bifurcation at Derout the Ibrahimieh canal is prolonged to some distance north of Beni-Souef for a length of about 195 kilometers.

The level of the bottom, below the distributing works at the head, is at present fixed at about 1 meter above the bottom of the feeder canal, or at 4.50 meters below the neighboring lands, and the bed has a slope of 6 centimeters per kilometer until the bottom has attained a depth of 1.50 meters below the level of the neighboring cultivated land, or at about the seventeenth kilometer from Derout. The slope of the canal then becomes the same as that of the valley, and the ordinary level of the water is maintained at the height of about 1 meter above the surface of the land.

Four works are established along the canal to facilitate the regulation of the water during low water. They are: an old bridge with nine arches, situated at the sixtieth kilometer, in a part of the ancient canal, whose bed the Ibrahimieh uses for a short distance, and three works, composed of three arches of three meters and a lock, are situated at Minieh (kilometer 70), Matia (kilometer 110), and Magaga (kilometer 138).

Immediately above these four dams are the outlets of the principal derivations.

The Ibrahimieh, except at a few points where it follows portions of ancient canals, is very regular in direction; it flows parallel to the Nile, and does not leave between itself and the river a distance of more than 4 or 5 kilometers.

The width of the bottom diminishes gradually from 20 to 12 meters, the embankments are 2 base to 1 vertical, with a berme 5 meters wide on each side above the ordinary level of the water; but here, as in most Egyptian canals, which are more or less deformed by deposits and irregular dredging, it is difficult to fix a typical cross-section.

Although locks have been established at Derout, Minieh, Mattai, and Magaga, the Ibrahimieh is not considered navigable, the last two locks have never been completed, and navigation is impossible between Derout and Mattai on account of an old bridge with nine arches mentioned above.

Many works recently constructed in the eastern dike of the Ibrahimieh allow, during high water, the emptying of the surplus into the Nile, and the maintenance therefore of a current sufficiently rapid to prevent, in a notable degree, the deposits of mud held in suspension.

Finally, a masonry syphon, composed of two openings 1.20 meters wide, has been constructed recently under the Ibrahimieh for a double purpose. In the first place, during the flood, it joins to the Nile a transverse canal connecting with the inundation basins of Minieh, to which it furnishes water provided directly by the river and strongly charged with mud; while, before the establishment of this work, this basin was only fed with water already partially settled. This same syphon serves in the second place, during high water, for the drainage of irrigable lands situated to the west of the Ibrahimieh, and in which the want of drainage has increased considerably the portion of saline material hurtful to cultivation; it is also a culvert which carries to the Nile the surplus of irrigation water.

Although the turbid waters have already deposited a great part of their mud before reaching the works of Derout, nevertheless it is necessary to dredge annually in the Deroutieh and Sahelieh; the same obtains for the first 20 kilometers of the Ibrahimieh below Derout. The amounts dredged each year on this section are:

	Cubic meters.
1882.....	92,000
1883.....	274,000
1884.....	330,000
1885.....	182,000

In 1886, by opening the regulating works along the canal during flood and allowing the water, whose surplus escapes to the Nile by several drains, to flow freely, the dredging of this portion of the Ibrahimieh has been avoided; but some earth-work is necessary in the upper pools of the secondary canals where some deposit takes place.

The Ibrahimieh canal having always water, the clearing is here effected by dredging.

Distribution of water.—As has been said, the feeder of the Ibrahimieh canal, under present conditions and with ordinary low water, discharges 50 cubic meters per second. This has not been the case very long, for in the years 1880, 1881, and 1882, at a time when excavation by means of dredges was not very well organized, the minimum discharges were, respectively, 38.27 and 30 cubic meters per second.

Taking as a basis the normal discharge at low water of 50 cubic meters, this volume of water it is estimated should be distributed at Derout in the following manner:

One-third to the Bahr Youssef to be utilized by Fayoum, as we will see further on.

Two-thirds to the canals of Ibrahimieh, Deroutieh, and Sahelieh. The 33 cubic meters thus disposed of by these three canals permit the cultivation, in summer crops, every year of about 42,000 hectares, which, taking into account the rotation of crops, corresponds to an irrigable area of 126,000 hectares.

The surface, cultivatable by irrigation, is separated from the region of inundation basins, fed by the Bahr Youssef, by means of a great longitudinal dike, of the usual type of Egyptian dikes, which extends, almost parallel to the Ibrahimieh, from Derout to the extremity of the canal.

The Bahr Youssef.—The Bahr Youssef is really a natural water-course, whose ancient bed is crossed by the Ibrahimieh canal at Derout, and which was formerly fed from the Nile. It trends immediately towards the west of the valley and hugs the Libyan chain, which it follows as far as Fayoum.

The Bahr Youssef has a very tortuous course. Measured along its general direction it has nearly the same length as the Ibrahimieh from Derout.

Its bed has a very variable section from point to point. In the most regular section the lesser bed is from 50 to 60 meters wide with a maximum depth from 6 to 8 meters. At high water the greater bed is limited by the dikes, and everywhere on the west by the mountains which also bound the valley.

The slope of the Bahr Youssef is almost equal to that of the Nile; its level, taken on a section across the valley, is therefore a few meters below the level of the Ibrahimieh canal, which runs parallel to it, and of the canals derived from the latter.

During low water the Bahr Youssef discharges about 17 cubic meters per second. At the time of highest water, which occurs when the basins which it crosses are being emptied, it discharges at least 850 cubic meters per second. Its water is therefore about 4.50 meters above the level of low water. The discharge, at low water, of the Ibrahimieh canal above Derout being hardly sufficient for the summer crops of the province of Fayoum, and the region of the irrigating canals of the provinces of Siout, Minieh, and Beni-Souef, it is necessary to stop all summer cultivation along the banks of the Bahr Youssef. Therefore during low water this water-course takes all its water to Fayoum.

During the flood it is utilized for filling the inundation basins, which are arranged along its banks from Derout as far as the dike of Kocheicha, then in the north of the province of Beni-Souef, for emptying the same basins and also for the discharge of the basins fed by the Sehagieh, between Derout and Siout. Also, and finally, it serves at the same time to carry to Fayoum the water intended to submerge the lands for the winter crops.

The basins fed by the Behr Youssef, and situated on the right bank of that river, are as follows :

Basins.	Area.	Remarks.
	<i>Hectares.</i>	
Tanouf	2, 229	Fed by the Bahr Youssef; emptied partly into the basin of Achmounin.
Achmounin	12, 566	Fed partly by the Bahr Youssef, partly by a cut in the dike of Deroutieh; discharges into the Bahr Youssef.
Tanachaoui	19, 293	Fed by the Bahr Youssef; discharges partly into this river and partly into the lower basin.
El Kuran-El Tahawi	8, 656	Do.
Dehri-Menkatin	7, 686	Do.
Burdanaoui	7, 875	Do.
Garnoussi	12, 337	Do.
Salagoussi	2, 656	Do.
Sultani	13, 399	Do.
Minieh	10, 573	Fed partly by a syphon under the Ibrahimieh.
Nuera	13, 711	Fed by the Bahr Youssef.
Bahabehin	21, 514	Do.
Kocheicha	33, 600	Fed by the Bahr Youssef; discharges into the Nile by a cut in the dike.
Total	166, 095	

There are also a few submergable lands between the Behr Youssef and the mountains, but these basins are of little importance.

This whole collection of basins, separated from the Nile by the Ibrahimieh canal, also fed throughout its whole length by the Bahr Youssef alone, is too extensive, for the lower basins only receive water too much settled and not very fertilizing. It was to overcome this inconvenience that the syphon of Minieh was built under the Ibrahimieh, as above mentioned, and many others have been projected.

The last transverse dike of this system of basins, the dike of Kocheicha, presents a remarkable peculiarity; it is the only dike in Egypt which is not entirely built of mud. It is built with an interior core of earth, retained above and below by masonry walls from 8 to 10 meters apart. This work serves, therefore, very well to secure the whole series of basins, and to prevent them from precipitating all their water upon the lower parts of the valley by rupture of the dikes.

Fayoum.*—This province presents characteristics entirely different from those existing in the rest of Egypt. The soil is lighter and the slope is much greater.

Fayoum forms a great basin scooped out of the desert. The low part of this region on the northwest side is occupied by a lake called Birket-el-Keroun, whose mean level is 40 meters below the sea, that is to say, almost 70 meters below the gorge which forms the only communication of this province with the valley of the Nile, and by which the Bahr Youssef brings it water. The distance of this gorge from Lake Keroun being 40 kilometers, the mean slope of the land in the direction of the lake is 1.80 meters per kilometer. To the west of Lake Keroun the slopes are sterile and abrupt.

The entrance to Fayoum, inclosed between two plateaus, leaving an open space between them of about 1,500 meters, is closed by a dike which completely separates this province from the inundation basins of the valley of the Nile. The Bahr Youssef crosses this dike by means of a masonry work called the bridge of Ellaoun, composed of three arches, one of 4 meters and the two others of 3 meters openings.

Fayoum was formerly cultivated by basins, like the whole of Upper Egypt, the bed of Bahr Youssef being too high to receive the Nile water at low water. Spring water, generally saline, still comes to this province during summer and still feeds the Bahr Youssef. These waters were far from being sufficient for the requirements, and it was necessary to economize them; thus has been created throughout the whole of Fayoum a very complete system of distribution by means of

*See Plate III.

masonry works, established along the principal canals and along the pools and reservoirs, which form the true basins of supply.

Since the Ibrahimieh has furnished water to the Bahr Youssef during low water, the summer crops have been much developed in Fayoum, and the inundation basins tend to disappear more and more.

The general system of canals is very simple here. After the bridge of Ellaoun, the Bahr Youssef continues as far as the chief place of the province [Medinet-el-Fayoum] whence start all the canals which water the province, forming divergent ways along which are arranged the special outlets and whose surplus flows into Lake Keroun.

In consequence of the abundance of irrigation water, the level of the lake has been raised some 4 meters in latter years, thus overflowing land heretofore cultivable; also the lack of drainage canals in the low parts has tended to render salt and sterile quite a quantity of land.

For the whole area of cultivated land in Fayoum, which is 97,000 hectares, it is estimated at present that the quantity of water to be given to the province might be, during low water, between 17 and 23 cubic meters per second, which might be raised during flood as high as 58 and even 80 cubic meters. But a part of this water is lost in Lake Keroun by defective distribution.

The mean amount of earth-work, which was formerly executed entirely by *corvée*, for the repair of canals and dikes reached, according to official figures, 1,300,000 cubic meters per year, or 14 cubic meters per hectare.

These works of repair, which are now done by contract, are estimated to-day as representing an annual expenditure of 295,000 francs, which amounts to 3 francs per hectare.

These amounts, very much less than those mentioned for the other provinces, are explained thus: Fayoum being far from the Nile the water which it receives is slightly charged with mud, and because the slope of the land is much greater than the rest of Egypt the velocity of the water here is much greater, and therefore the deposits are less considerable.

CHAPTER IV.

DESCRIPTION OF THE MOST IMPORTANT IRRIGATION WORKS IN LOWER EGYPT.

ISMAILIEH CANAL—GREAT DAM AT THE POINT OF THE DELTA—PROVINCES SITUATED TO THE EAST OF THE DAMIETTA BRANCH—PROVINCES OF THE CENTER—REGION OF THE WEST, OR PROVINCE OF BEHERA.

I. ISMAILIEH CANAL.*

The Ismailieh canal, although it belongs to the irrigation system of the provinces to the east of the Delta, deserves nevertheless a separate description. It is, in fact, the only important canal in Egypt which has been constructed throughout by contract, and which has been constructed as a single job. There results a regularity in its flow and profile which the other canals, built by the *corvée* are far from possessing; it is much oftener used for navigation than irrigation. It was constructed, in virtue of agreements between the Egyptian Government and the Suez Canal Company, for the purpose of creating a navigable water-way between the Nile and the maritime canal; to furnish water for irrigating some lands conceded to the company, and finally to provide for the needs of the maritime canal and the towns and stations established along its course a daily supply of 70,000 cubic meters. According to the specifications the bottom of the Ismailieh was to be established so that the depth of water should always be $2\frac{1}{2}$ meters at high water, 2 meters at mean stage, and 1 meter at low water.

The Ismailieh canal has its inlet at Cairo; it has two inlets—one called the Kasr-el-Nil, in the heart of Cairo, is the oldest, but it is only utilized as an accessory on account of its want of solidity; the other, called Choubrah, is situated 7 kilometers below. The canal kilometers are always counted from the old inlet; the branch leaving Choubrah is 4 kilometers long and joins the main canal at the ninth kilometer.

Running at first to the northeast the Ismailieh follows the edge of the desert until it reaches the little valley of the Ouadi, which it crosses and follows the north side, trending direct to the east as far as the town of Ismailia, where it discharges into Lake Timsah. A branch, which begins a little before Ismailia, stretches toward the south across the desert, following a line parallel to the maritime canal and empties into the channel of the port of Suez.

The line of the Ismailieh conforms at many points to the direction followed by the ancient canal, which, according to historians, put the Nile in communication with Lake Timsah, or with the Red Sea itself, and of which traces have been found on the surface.

The length of the canal between the Nile and Lake Timseh is 136 kilometers, and the length of the Suez branch is 89 kilometers.

The width of the bottom is 13 meters; the slopes are generally 3 base to 1 vertical up to the level of the soil, with a slight berme of 50 centimeters wide 2 meters above the bottom. The crest of the embankments, having a thickness at the crown of 7 meters as a minimum, was originally fixed at 11 meters above the bottom from the head to the twentieth kilometer, thence at 9 meters as far as the fifty-fourth kilometer, and finally at 5 meters for all the rest of the canal; but these profiles

* See Plate IV.

of the embankment have now been modified in many places by the earth taken out by dredging. A banquette of 8 meters wide is generally arranged between the foot of the embankment and the crest of the slope of the canal trunk.

In sandy localities the slope of the canals are held at 6 base to 1 vertical from the bottom to the summit of the embankment.

On the Suez branch the normal width of the bottom is only 8 meters; but it is not everywhere kept to this dimension and in certain places it does not exceed 5 to 6 meters.

The longitudinal profile for the first 98 kilometers has a slope of 42 millimeters per kilometer; at the ninety-eighth kilometer a fall of 60 centimeters is obtained by the Gassassine lock; the slope of the canal then becomes 20.5 millimeters per kilometer as far as Ismailia, where the bottom of the canal is 4.30 meters above the level of Lake Timsah. This difference of level is overcome by two locks. On the Suez branch the mean slope of the bottom is 25 millimeters per kilometer.

At Cairo the trunk of the canal has been excavated to 1 meter below the level of the lowest known water, or to the 9.725 meter mark above the sea level, and to a depth of 11.90 meters below the top of the wharves* and adjoining land.

At the crossing of the valley of Ouadi the canal is in embankment, and the level of the water is 2.50 meters above the adjacent land. This causes frequent infiltration, which extends quite a distance along both banks, and, no arrangement having been made for drainage, large areas, formerly cultivated, have been ruined.

Fine regulating bridge-dams with locks, including the work at the Choubrah head, are arranged along the canal as far as the Suez branch, not including the second inlet work on the Nile, called Kasr-er-Nil, almost abandoned, which is composed of six arches with 3 meter openings and a lock 6 meters wide.

These works† are designated as the locks of Choubrah, Siriakos, Belbeis, and Gassassine. Except at Gassassine, the bottom of the canal has no fall due to these works, which only differ by the variable height of the chamber-walls. They are composed of a lock 8.50 meters wide and 59.50 meters total length, with an available length of 38.50 meters; in one of the chamber-walls of the lock is built a regulating work, composed of two openings 2.75 meters wide, separated by a pier 2.50 meters thick; the openings are formed by an arch of 1.25 meters radius, supported upon vertical piers 2.50 meters high.

Lateral culverts, 1.90 meters high and 70 centimeters wide, are built in each one of these lock walls, and afford communication between the pool above and the interior of the lock or the pool below. The lock is provided with an iron gate with shutters.

The openings and lateral culverts are closed by means of cast iron shutters.‡ The works are not built upon a solid subsoil; their foundations are generally about 3 meters thick.

Bridges, having a movable span across the lock, are placed above each bridge dam; this movable part is composed of an iron draw on all the works, except at Choubrah, where they have built a turn-bridge, of two wings 9.50 meters wide between parapets.

The terminal locks of Ismailia are of the same type as the others, but they have lift-walls and no regulating works built in them.

The locks of the Suez branch, of which there are five, and the first of which is at Neficha, the head of this branch, and the other four at the sixteenth, forty-second, and sixty-eighth kilometers and at Suez, have no dams built, but are furnished with the lateral culverts, permitting the establishment of a current in the canal.

Among the other necessary works for the regulation of the Ismailieh canal are two outlets:

One, about the seventy-fifth kilometer, on the right bank, is composed of three openings of 3 meters, with piers 1 meter thick, closed by stop-planks, and intended to empty into the Ouadi, whose level is 1.10 meters lower than the Ismailieh canal, a part of the surplus water.

The other, situated at Nefiche, near the city of Ismailia (one hundred and twenty-ninth kilometer), contains five openings of 2 meters, closed by stop-planks, and separated by piers 1 meter thick and 3 meters long; the sill of this outlet is 2 meters above the bottom of the canal; it sends the surplus water into Lake Timsah.§

* See Plate VII, Fig. 2, for designs of these wharves.

† See Plate VIII.

‡ See Plates IX and X.

§ See Plate XI.

A number of outlets, more or less important, connect the Ismailieh canal with the network of canals which water the provinces of the eastern part of the Delta; these outlets have in general iron fermetures. The most important of the communications is that which is established with the Ouadi canal, about the seventy-fifth kilometer; a lock constructed at the point of junction of the two canals, with a lift-wall of 1.60 meters, the level of the Ouadi canal being below that of the Ismailieh canal; this canal only serves for irrigation in the first part of its course, and the Suez branch flows through the open desert.

The minimum discharge fixed for the Ismailieh at low water is 17.36 cubic meters per second.

At high water the discharge is nearly the same. From this it results that the muddy water, coming into the canal with a very weak velocity, at a depth of about 5 meters, causes considerable deposits in the first pool, which it is necessary to dredge each year. The small extent of existing inlets and the low height of the banks in the lower pools forbid a free entrance of the Nile into the canal at high water. They always decrease notably the volume of water by closing almost completely the works at the head during high flood, taking the greater part of the necessary water by means of an opening in the second pool, which connects the Ismailieh with a secondary canal called Chibini; the water thus introduced is then far enough from the Nile to have deposited all its mud.

The annual dredging in the Ismailieh, which was formerly more than 300,000 cubic meters, not including the work in the ancient arm of Kasr-el-Nil, is found by this means to be reduced by at least 150,000 cubic meters. The greater part of this work is required to clear out, on the side of the Nile, the inlet itself of Choubrah; the work at the head is in reality established not upon the bank of the river—it is almost 500 meters distant, and is connected by a channel whose head is backed up every year by the back water of the flood.

II. THE GREAT DAM OF THE APEX OF THE DELTA.

The general view given above of irrigation in Lower Egypt has already shown the important part which the great dam established at the apex of the Delta was destined to fill, and the small rôle to which it has been reduced in consequence of its unfinished condition and the economy which was introduced in the foundation.

In spite of these defects, this dam is nevertheless a grand work. It was undertaken with much boldness by M. Mougél-Bey, engineer des ponts et chaussées, about 1843, at a time when the use of movable dams was little known, when there had not yet been projected a work of such importance in the deltas of great rivers. Unfortunately, he experienced in his undertaking all the vicissitudes which works requiring a long time undergo in this country; at first begun with feverish activity, then neglected and abandoned, and finally put in use before it was even finished.

This great dam was constructed at the exact locality where the two arms of the Rosetta and Damietta separate. *It consists really of two dams, each established on one of the arms, including between them a tongue of land about 1,000 meters wide, which forms the point of the Delta; this is bounded by a circular wharf† and is cut in the middle by the great canal of Menoufieh, which is designed for the watering of the land included between the two arms of the Nile and takes its water from the pool above the dams.

The dam of the Rosetta branch is formed of sixty-one arches of 5-meter openings separated by piers 2 meters thick; at each extremity is a lock, one 12 and the other 15 meters wide; the total length of the work is 465 meters.

The dam of the Damietta arm is identical with the preceding, except that it has ten more arches; its length, therefore, is 545 meters.

According to the project, the pool created by this work was to be, at the maximum, 4.50 meters above the level of low water, supposed to be 11.80 meters above the level of the sea; the water of the pool above was thus to be held at 16.30 meters, that is, very nearly at the level of the cultivated lands at this locality. But it was afterward found that if the water necessary for the irrigation of the whole of Lower Egypt was taken from the pool above the dam, the level of the

* See Plate XII, Fig. 1.

† See Plate VII, Fig. 1.

pool below would be much less than 11.80 meters, and it was necessary that this level should be at least above the 10-meter mark; the dam then, in order to obtain the required height, should secure a pool of 5.80 meters.

The foundation* consists of a bed of beton covered by a layer of brick with belting courses of cut stone; the total width of the bed is 34 meters, with a thickness of 3.50 meters, with retaining walls above and below 5 meters in height. The foundation bed is prolonged below by an apron 8 meters long, formed of a bed of stone of a mean thickness of 1.50 meters covered by a bed of beton 1 meter thick, with a slope of 20 centimeters per meter. This apron is terminated by a mass of beton 4 meters wide and 3 meters thick. The total width of the foundation bed is thus 46 meters; riprap strengthens the bed of the river below.

In the Damietta arm and the greater part of the Rosetta arm the bed is built on the mud; but in the middle of the Rosetta branch, where at the time of construction the bed of the river was lower than was the intended level of the bottom of the foundation, they simply, for about 70 meters in length, to even up the bottom, threw in riprap upon which beton was spread to the proper depth. This mass of riprap reached to a depth of 12 meters below the beton masonry.

It has for a long time been doubted whether in this country such a foundation would stand under a pressure of 5 to 6 meters of water, and, in fact, the dam to this day having, owing to various circumstances, never been required to stand more than 3 meters pressure, it can not be said what would be the effect of a greater pressure of water on the mass of riprap; nevertheless, the English engineers now in the Egyptian service affirm that in India, where there are large dams built on river mud similar to that of the Nile, they often, to economize masonry, have raised the bed by means of sand filling, or stone riprap; the water filters for a certain time through these masses, which soon become an impermeable barrier. M. Fowler, in one of his reports on the Nile dam, mentions, among other things, the case of works built under these conditions on the Kistnah and the Godavery in India as having been perfectly successful.

However this may be, it seems certain that beton established on riprap, on the Nile, has been put in without the proper precautions, that the greater part of the mortar has been carried away by the current, which filters through the masonry, and therefore that the masonry does not present the necessary resistance to withstand a great pressure. In consequence of this fact, when it is desired to use the dam, cracks formed in many places and settling occurred; coffer-dams were often built in the most threatened places, but in spite of everything they have never dared, until the last few years, to subject the dam to a pressure of more than 2 meters of water.

The piers are 2 meters thick, 15 meters long, and 10 meters high; they support full center arches forming a bridge 10 meters wide between heads; the top of the piers are at the level of high water.

The system of fermeture first projected, and which has been arranged for the Rosetta arm only, is complicated and very imperfect; it is composed of sheet-iron gates of cylindrical form turning about a horizontal axis and carrying many floats designed to lighten them in the water and thus facilitate their maneuvering. These gates do not give a tight fermeture; in fact, it was thought that the discharge of the Nile at low water was sufficient to allow a great part of it to flow through.

Until the last three years, the dam of the Damietta not being furnished with apparatus for closing it, they were content to close the Rosetta arm, at least partially, and thus obtain a pool of two meters. This choking of the river allowed a quite plentiful supply for the central canal or the Menoufieh, and the Damietta arm supplied all the water for the provinces of the east and center of the Delta. But since 1882 they determined to use this work more thoroughly; for this they shut the Damietta arm partly by means of stop planks, and the Rosetta arm as completely as possible; they obtained thus a pool of 3 meters above low water at the Rosetta arm and of 1.60 meters at the other, and were able to largely feed the central canal and increase the discharge of the canals situated on the right bank of the Nile between the dam and Cairo.

To obtain this result without compromising the stability of the dam, M. Willcocks, the engineer in charge of the direction of this work, employed an ingenious method which consisted in

* See Plates XIII and XIII bis.

diminishing the pressure on the foundation bed by dividing the total fall of 3 meters into two falls of 1.50 meters each. For this purpose along the extremity of the apron for the whole length of the dam a dike of riprap* was established, whose crest, 2 meters wide, was 3.25 meters above the level of the apron; in spite of its permeability this dike was sufficient to create a difference of level of 1.50 meters, and it reduced thus the pressure on the apron to that of a fall of 1.50 meters. Now it is proposed to strengthen and place the dam in such condition that it may produce normally a pool of 4 meters, that is to hold the water above at a level of 14 meters at low water; projects have been elaborated for this which will shortly be executed, and which consist particularly in strengthening the apron, repairing the bad portions, erecting iron apparatus for fermeture of easy maneuver, and in strengthening the bed of the river below by strong and massive riprap.

III. PROVINCES SITUATED TO THE EAST OF THE DAMIETTA ARM.†

The watering of the provinces of Lower Egypt, situated to the east of the Damietta arm, is accomplished at present by seven principal canals leading from the Nile and by their branches. Three of these canals are between Cairo and the dam; they are the Ismailieh, the Cherkaouieh, the Bessoussieh. The other four are below the dam; they are the Bahr Moez, the Sahel, the Om Salama, the Mansourieh.

The Ismailieh canal.—This canal has been mentioned above; it is not necessary here to go over it; it is able to contribute to irrigation along its course, because of its constant discharge of at least 11 cubic meters per second.

Cherkaouieh.—The Nile mouth of this canal is about 12 kilometers above the dam; it is formed by a masonry work, reconstructed a few years ago, and composed of five arches of 2.40 meters, closed by stop-planks.‡ The level-mark of its sill is 2 meters below the level of low water, but the bottom of the canal at the mouth is held at the 11.50-meter mark, or at 1.50 meters below the highest pool obtained hitherto at the great dam.

The work is of brick and of cut stone; the bed lies on a foundation of sand; it is of beton, and has a thickness of 2 meters with retaining walls 2.70 meters high above and below; it is covered with two overlying layers of brick masonry laid on edge. The piers are 2 meters thick, 11.25 meters high, and 15.80 meters long; they support a bridge 8 meters wide.

The bottom of the canal is 10 meters wide, and the slopes are 2 base to 1 vertical; the longitudinal slope is quite irregular on account of defects in dredging; the normal slope should be 4 centimeters per kilometer.

This canal follows a line almost parallel to the Ismailieh canal for about 28 kilometers of its length; here it separates into two branches, of which one, the Ohibini, communicates with the Ismailieh canal at Zaouamel by an inlet formed of two arches of 2.50-meter openings.

The canals derived from the Cherkaouieh carry the surplus of their water to the eastern part of Lake Menzaleh.

At low water this canal discharges easily 6 to 7 cubic meters per second, especially since they have obtained a good rise in the water above the dam of the Delta.

During flood the Cherkaouieh receives a supply of water 5 to 6 meters in depth.

Bessoussieh.—This canal has its mouth 2 kilometers below that of the Cherkaouieh. The work at the head is an old bridge-dam, composed of three arches, one of which has an opening 3.60 meters and the other two openings of 1.90 meters, closed by vertical stop-planks. The bottom of the canal at the mouth is held at the 11.60-meter mark, or 1.40 meters below the highest level obtained hitherto at the great dam. Its width is fixed at 8 meters, and the slope is 4 centimeters per meter.

The Bessoussieh follows at first a line nearly parallel to the Nile for 12 kilometers of its length. It is designed in this portion for watering the high lands which border the river, then it ramifies into two principal branches, the Filfleh canal, which still flows parallel to the Nile, and the Abou Akdar, an ancient Pelusian branch, which empties into Lake Menzaleh.

* See Plate XII, Fig. 2.

† See Plate IV..

‡ See Plate XIV.

The discharge of the Bessoussieh at low water is 5 to 6 cubic meters per second.

Bahr Moez.—The Bahr Moez leaves the Nile 70 kilometers below the dam. It has no masonry work at its mouth. It is an ancient arm of the Nile, 60 to 80 meters wide, which flows freely as far as Zagazig, for 40 kilometers following the ancient bed of the Tanitic branch. At Zagazig this water-course is provided with distributing works, established at the heads of different canals which branch from it. One, the Onadi, is provided with a lock, and forms a navigable communication between the Bahr Moez and the Ismailieh canal. The Bahr Moez is itself dammed at Zagazig by a work composed of nine arches, with openings of 2.30 meters.

The normal discharge of the Bahr Moez is to-day, at low water, 23 cubic meters per second, but it seldom attained this amount except in the last few years, for it formerly discharged from 10 to 15 cubic meters only.

The level of the Bahr Moez at its head, formerly fixed at 6 meters below the neighboring cultivated land, or at 6 meters above the sea, is now held a little above this, because instead of annually dredging this canal to the 6-meter mark they prefer to raise the water of the Nile 1 meter by means of a temporary dam.

The employment of these temporary works dates from 1885. It affords a temporary solution for feeding the Bahr Moez during low water until the works for placing the great dam of the Delta in working condition are completed and allow the water to be brought by a lateral canal from the Nile. The temporary work was as follows. Since a more complete fermeture of the Damietta arm has been obtained at the point of the Delta, the canals which have their inlets on this branch have with difficulty maintained their discharge, and, in fact, in 1884 it was very difficult to obtain water for the irrigation of the northern portion of the eastern provinces. To remedy this inconvenience it was decided to build across the Nile, a little below the head of the Bahr Moez, a massive riprap, damming the bed of the river and forming a dike 430 meters long and 25 meters wide at the crown. A maximum rise of the water of 1.10 meters was thus obtained, which signally improved the supply of the Bahr Moez and gave it even much more water than was necessary. This temporary dam contained 16,000 cubic meters of stone. It cost about 65,000 francs, which is much less than would have been expended for dredging the Bahr Moez to a depth equal to the damming up of the water. When the Nile began to rise as great a part as possible of the stone was taken out and placed on the bank, to be utilized the following year. The remainder was left in place, and caused only an inappreciable rise in the flood level, the section of the lesser bed upon which the dike was built being only a small portion of the greater bed.

For this work, and also at other places where stone for riprap or spurs is too expensive, as a substitute they have used blocks of rough brick. This material is manufactured in ordinary brick kilns; the earth is cut in the form of bricks, roughly squared, dried, placed in the kiln and burnt so that some portions are vitrified, and agglomerated pieces of more or less size are then drawn from the kiln, broken into irregular shapes, and may be employed in riprap; the soil of Egypt, almost everywhere, is adapted to the fabrication of these blocks.

Sahel Canal.—The Sahel Canal has its inlet 2 kilometers below the Bahr Moez. Designed for the irrigation of the high lands between the river bank and the territory to the east watered by the derivations of the Bahr Moez, it follows the banks of the Nile for a course of 30 kilometers and then diverges, under the name of Bouhieh Canal, to empty in the Lake Menzaleh.

The work of the inlet consists of six arches of 2.50-meter openings, closed by stop-planks; the bed is at the 6.07-meter mark above the sea; the mean width of the bottom is 10 meters, and the normal slope is 6 centimeters per kilometer.

The mean discharge of the Sahel Canal is from 10 to 12 cubic meters at low water; it has been notably increased for the last two years by the temporary dam just mentioned, and which was placed below the inlets of the Bahr Moez and Sahel, in order that the rise in the water might be taken advantage of by both canals.

Mansourieh and Om Salama Canals.—These two canals have their inlets very near each other, and 110 kilometers below the dam of the Delta. Each is provided at its head with a masonry work composed of three arches of 3-meter openings. The aprons are at the 2.79-meter mark for the Om Salama, and at the 3.44-meter mark for the Mansourieh, the level of the soil being about the 9.30-meter mark; but the canals are not dredged out to the level of the apron.

The two canals follow two lines slightly apart and parallel to the general direction of the Nile, to which the Mansourieh is the nearest, being designed for the irrigation of the high lands. About the fortieth kilometer they separate, the Om Salama being prolonged by the Bahr Tanah, which inclines at first towards the east, and the Mansourieh by the Bahr Saghir; both, after following a sinuous course and an irregular profile, empty into the western part of Lake Manzaleh.

The mean combined discharge of both these canals, at low water, is 18 cubic meters per second. This discharge was notably increased in 1886 by the construction, below their head during low water, of a temporary dam similar to that of the Bahr Moez and Sahel.

This work *erected at the point where the greater bed of the Nile is 450 meters wide, and where the floods attain an altitude of 11.50 meters, has its crest at the 5.50-meter mark; it has a length of 239 meters and a maximum height of 4.40 meters above the bottom. For 82 meters of its length, in the portion where the bed is the highest, it is a simple earthen dike; for the remaining 157 meters it is composed of a riprap of stone and blocks of rough brick; a platform 18 meters wide is arranged at the 4-meter mark, and is surmounted by a small dike 1.50 meters high and 1 meter crown. A rise of 80 centimeters is thus obtained, sufficient to assure an abundant discharge for the Om Salama and Mansourieh canals, which, from unforeseen circumstances, have not been dredged to a depth sufficient to secure proper irrigation for the region without this artificial elevation of the water level.

From the lower extremity of the Mansourieh Canal, at the point of junction with the Bahr Saghir, a second canal about 60 kilometers long branches off; this follows a line parallel to the Nile, and is specially designed for the watering of the rice fields as far as Damietta. This canal, which is called the Cherkaouieh of Damietta, had a few years ago an inlet on the river, but it has been closed and is to-day completely out of use.

Such are the principal canals which serve for the irrigation of the eastern provinces of Lower Egypt. They are of two kinds—some, as the Bessoussieh, the Sahel, and Mansourieh and its prolongation, the Cherkaouieh of Damietta, serve at least in the upper portions for the watering of the high lands along the Nile; the others, as Ismailieh, the Cherkaouieh, the Bahr Moez, and the Om Salama, start immediately from the river and carry their water directly to the distant and lower lands.

The description of the different Egyptian canals does not show great precision in reference to the section, discharges and slopes, and works for regulating the water. This is due principally to the instability of the present condition of irrigation, and to the variation which the role of each canal has undergone for some time, and its importance in the general net-work.

Thus the information given above, except as it concerns the works of skill, should only be considered approximate.

On the other hand, every year an enormous quantity of mud modifies entirely, for great lengths, the dimensions of the canals. The removal of these deposits is not made with perfect regularity, and as these deposits consist of the same mud as that in which the canal is excavated, it would be in general very difficult to distinguish at the end of a certain time the primitive form of the section. They are described only by typical profiles, which have become entirely theoretical and which have no relation to the actual state of affairs. Even the masonry works can only in certain cases give an indication of the normal width of the canal, and not of its depth, because often dredging has not been carried even to the level of the apron. This is why, in the description of the irrigation of a region, instead of entering into detail, often useless, we are obliged to confine ourselves to a few summary indications of the position and the general direction of the principal trunk of the most important canals, without occupying ourselves with the dams which are established from point to point, or the inlets or branches which distribute the water, some at low water and others only at flood.

The lands of the eastern provinces which are the least favorable for summer crops are those which are nearest the point of the Delta, and especially the province of Galoubieh. In this portion, in fact, the soil is more than 5 meters above low-water level and 3 meters above the pool of the dam. It is necessary, then, to use elevating-machines to water the land. At certain points it

*See Plate XV, Figs. 4 and 5.

is necessary even to elevate the flood water in order to make winter crops. As we approach the sea the difference of level between the soil and low water diminishes, and consequently the expense of irrigation decreases. At a certain distance from the Nile, with a good system of distribution, the raising of water may be dispensed with for nearly the whole year, because it reaches the same level as the soil, but farther the lands are too low, and they are in danger of being damaged by the overflow and infiltration of the water above.

The total area of cultivated land in the eastern provinces is 455,000 hectares. There would be needed for summer irrigation, under favorable conditions, according to approved estimates, 275 milliliters per hectare to insure for these provinces a constant supply of 12 cubic meters per second. Now, according to official reports, the quantity of water furnished during low water, which was 100 cubic meters in 1880 and 81 cubic meters in 1881, was only 66 cubic meters in 1882, a year of disorder for Egypt, during which the work of dredging was badly executed. It is seen by this how the results of a bad administration are felt and affect quickly the prosperity of the country, and how fragile is a system of irrigation which can not stand, without great damage, a single year of neglect. Since 1882 a larger discharge, exceeding perhaps the 125 cubic meters necessary, has been given this region, but unhappily this volume is badly distributed on account of the difficulty met with in supplying the canals situated to the northward. It results that certain lands have not been cultivated, some because they were too dry and others because they were injured.

To assure under good conditions the watering for summer and winter in these provinces it is necessary to remove annually enormous volumes of earth. There are in fact public works, including the strengthening of the bank and dikes, to be executed in these provinces each year of about 6,000,000 cubic meters of earth-work, or more than 13 cubic meters per hectare. This volume may perhaps have been diminished in late years by the improvement adapted for the distribution of water. Still the annual expenses of the care of the canals and dikes of this whole region is estimated at 2,600,000 francs, which represents an expenditure of about 5.70 francs per cultivated hectare.

IV. PROVINCES OF THE CENTER.

Until last year the irrigation of the province comprised between the two branches of the Nile was accomplished by means of five principal canals, each having an inlet from the Nile.

The Rayah Menoufieh, much the most important, with an inlet above the great dam at the apex of the Delta; the Bahr Chibine, the El Atef canal, the Hadraouieh canal, the Sahel canal.

The four last have their inlets upon the Damietta arm between the fiftieth and sixtieth kilometer below the dam. To-day, during low water, all the irrigation water of these provinces is furnished by the Rayah Menoufieh and by the Hadraouieh canal, all the great canals having been placed in communication with the Rayah Menoufieh, and their outlets from the Nile having been closed. The Hadraouieh canal will also, according to present projects, be connected with the Rayah Menoufieh, which will then provide all the irrigation for the region comprised between the two arms of the Nile. At the time of autumn crops it will doubtless always be necessary, at least for some time yet, to have recourse to the canals along the Nile, as it has been shown that at this epoch the discharge of the canals should be for several days equal to four or five times what it is during low water.

The principal canals thus have their inlets in the southern portion of the Delta, consequently, their direction being from south to north, they form a fan between the Rosetta and Damietta arms. The greater part of the most important canals of this region are nothing but ancient arms of the Nile, and notably the Bahr Chibine, which occupies the bed of the Sebennitic arm.

The Rayah Menoufieh is a wide canal; its inlet is composed of six arches of 4.16 meter openings, closed by stop-planks, and a lock 15 meters wide. The apron is 9.75 meters above the sea-level, and the total width of the bed varies from 50 to 55 meters, with a pool at the dam of the Rosetta arm of 3 meters (13 meters above the sea-level); this canal has a discharge of nearly 115 cubic meters per second.

The Rayah Menoufieh trends towards the north, approaching at first the Damietta arm; some secondary canals branch from it for the irrigation of the high lauds situated between it and the

Rosetta branch. About the twenty-second kilometer it feeds two branches, the Sersaouieh and the Bagourieh, which flow toward the northwest; the Menoufieh then meets the Bahr Chibine, and continues as far as the El Atef canal; then, by means of a derivation which crosses the Hadraouieh canal, by means of culverts, it takes the water to the Sahel, a canal designed to water the high lands bordering the Damietta arm.

The Bagourieh and the Sassaouieh are more especially designed for watering the lands situated towards the east, and the Bahr Chibine, by itself or its branches, waters the middle region. All these canals, or their ramifications, reach Lake Bourlos, where they empty their surplus water, with the exception of the Bahr Chibine, which empties directly into the sea, and the canals situated between the Bahr Chibine and the Damietta arm, whose surplus water is discharged into the Bahr Chibine itself or returned to the Nile opposite Damietta.

In all this region of the Delta, where a dike can only be built by making a borrow pit in the neighboring soil, they often utilize as irrigation canals the trenches which were necessary all along the railroad to push forward the establishment of the roadway. This occurs notably for the greater part of the lower line of the Sahel canal.

The area of the lands at present cultivated in this part of the Delta being 500,000 hectares, without counting the marshy region, the littoral dunes, and Lake Bourlas, the quantity of water necessary to be supplied at low water is 138 cubic meters per second, but so large a quantity of water has not yet been supplied.

Without counting the work of clearing the trenches and small canals which concern only individuals, 6,300,000 cubic meters has been estimated, since several years, as about the total annual amount of earth-work to be executed by the *corvées* to repair the canals and dikes of the provinces of the center of the Delta, or 12.60 cubic meters per hectare. Efforts have frequently been made of late years to reduce this volume, and to-day the annual expenditure is estimated at 1,600,000 francs simply for these repairs, or 3.20 francs per hectare. This amount is not relatively great when compared with that shown for the other parts of Egypt. This result has been obtained by the suppression of most of the direct inlets from the Nile, which was accomplished by joining all the great canals to the Rayah Menoufieh, and by establishing a judicious system of distribution, consisting in never allowing the muddy water to remain in certain pools with low velocity; the amount of deposit has been much reduced. Another ingenious method has given very good results in decreasing dredging. The Rayah Menoufieh feeds on its left bank, at about the fifth kilometer, the Naggar canal, from which a short distance from its mouth branches the Om-el-Sebel, then about the tenth kilometer it supplies the Nanaieh canal.* There three secondary canals run almost parallel in a northwesterly direction and reunite, after a course of about 25 kilometers, not far from the Rosetta arm. Formerly, to irrigate the riparian lands, which are very high during flood, they closed the gates, situated a little below the mouth of these three canals; this caused the water remaining in the upper pool to settle and deposit here annually a total volume of 900,000 cubic meters of mud. Mr. Willcocks, inspector of the Delta irrigation, conceived the idea of establishing upon each bank of the canals a small parallel canal of little depth, having its inlet on the Rayah Menoufieh and terminating at nearly the same level as the first regulating work of each canal. Under these conditions, at the moment when the height of the flood was sufficient to give water to the lands, they partially opened the first regulator of the three deep canals so that a current of red water was established and flowed at the level of the lands situated below these regulators. For the lands situated above these regulating works they use small canals of little depth, from which the deposits of mud which are formed are easily removed at small cost. A drainage canal also permits the return to the Nile of the surplus of muddy water which circulates thus, without diminution of velocity, in the three canals of Naggar, Om-el-Sebel, and Nanaieh. By this arrangement the volume of dredging has been reduced from 900,000 to 256,000 cubic meters, and a saving of more than two-thirds effected. The execution at small cost of canals of this kind, whose cross-sections and lengths are naturally very limited, affords thus a great relief to agriculture.

* See Plate XII, Fig. 3.

V. REGION OF THE WEST, OR PROVINCE OF BEHERA.*

The region situated to the west of the Rosetta arm, which forms the province of Behera, is the least important of the three portions of the Delta; in fact it contains only 196,000 hectares of land now cultivable. It comprises, on the south, a narrow strip of land whose width does not exceed 3 to 4 kilometers, and is often considerably less, extending along the Nile, below the dam, for about 70 kilometers. To the north the cultivated lands spread in a triangle bounded on the west by the desert, on the east by the Nile, and on the north by the sea, or rather by Lakes Mariout and Edkou, which form a girdle along the sea-shore.

The irrigation of the province of Behera is effected under very special conditions. At the period of cultivation by basins the lands were inundated by a number of shallow canals arranged along the left banks of the Nile and trending in a westerly direction. When watering was introduced into the country a canal, called the Katatbeh, was dug with an inlet from the Nile, about 40 kilometers below the position of the dam, crossing the province from one end to another and cutting all the inundation canals, to which it was in future to furnish water during low stage and during flood.

At the same time, to furnish fresh water to Alexandria, and to connect it with the Nile by a navigable water-way, the Mahmoudieh canal, having its inlet at Atfeh at the two hundred and tenth kilometer of the Rosetta arm, was opened. It was sufficiently low to be able to have water the whole year, and follows a general direction from east to west. This canal receives throughout its course the surplus water of the Katatbeh.

Some years later, about 1850, the inlet of Atfeh was closed by deposits of mud, and the canal itself was partially filled up. As they had great difficulty, with the means of working then possessed by the country, in maintaining, by dredging, the bottom at its proper level, they determined to raise the water into the Mahmoudieh by steam-pumps established on the banks of the Nile itself.

Very soon the extension of summer crops compelled the insurance of more regular discharge for the Katatbeh, and first made the necessity felt for the distribution of the water for irrigation at a higher level. They then moved the inlet of this canal 40 meters up-stream to a point above the great dam. The new channel thus constructed, between the old mouth of the Katatbeh and the dam, is called the Rayah Behera.

Unfortunately, the Rayah Behera is established for a great part in the desert, whose sands encroach on it; it is also dug in a very movable soil, so that it requires every year enormous dredging. As the province is too small, already overburdened with other works, to have such considerable earth-works imposed on it, recourse was had to aid it to the contingents of the *corvée* furnished by other provinces. On the other hand, with the low pools obtained by the dam, this canal was not capable of giving a sufficient supply for all the crops of the region. This state of affairs could not last, and in 1880 they allowed the Rayah Behera to be filled up, and arranged steam-pumps near the old inlet of the Katatbeh so as to furnish this canal all the water needed at low water and at a sufficiently high level for the crops on the lands situated on the banks of the Nile. At the same time, the summer crops having been developed along the Mahmoudieh canal, they increased the machines established at Atfeh. All the water of the province of Behera could thus be provided, during low water, by the establishments of Atfeh and Katatbeh, and by numerous special machines established along the banks of the river. The projects now in course of execution have caused the irrigation of this province to enter a new phase. In fact, as soon as the work of finishing and strengthening the great dam is completed, so as to obtain a sufficient damming of the Nile water, it is the intention to re-establish the Rayah Behera by the employment of dredging-machines, if necessary, for the excavation and repairs, and to use it to supply all the region of the west Delta; the elevating machines established at the head of Katatbeh and Mahmoudieh may then be dispensed with.

For the moment these hydraulic machines constitute the principal point of interest in the irrigation of the province; they are probably the most powerful plants in the world employed for raising water for irrigation.

* See Plate IV.

Rayah Behera.—The inlet of the Rayah is a few meters above the great dam; it is provided with a masonry work having 21.20 meters of clear openings; the level of the apron is at the 8.85-meter mark, or 65 centimeters above the level of the apron of the great dam.

The length of the canal is 42 kilometers from its head to the Katatbeh. In the original profile the width at bottom was 20 meters, and the slopes were 2 base to 1 vertical, except in sandy portions the mean slope was 10 centimeters per kilometer. But, time and again abandoned and replaced in service, this canal is now almost filled up for the greater part of its course.

What renders the keeping up of the Rayah Behera specially difficult, at least in its upper portion, is that the banks, which are here of sand, degrade under the action of the current, and their falling in fills up the bed; this effect is much more marked, since every year it is necessary to throw into the canal, during flood, considerable quantities of water, for, having cut off the reflux of the inundation basins of the province of Giuzeh from the Nile, which used to enter below the dam, it serves now as a drain for these basins, and their drainage water assumes here a velocity much greater than obtained in the pools, all along the Rayah, its slope being relatively strong. It was hoped that by keeping here, during the entire flood, a rapid current of water, these deposits might be carried away, but up to the present this has not succeeded, and the crumbling of the banks has continued to raise the bottom. To replace the Rayah in service, it will be necessary to excavate anew for the greater part of its length. According to the present projects the level of the sill of the inlet will be held at 10.60 meters, the slope at 75 millimeters per kilometer, and the width at the bottom at 16 meters. We might cite, among the causes for the filling up of the canal, the wind of the desert which drifts the sands, but this is but a secondary cause and certainly does not produce a fill of more than 10 centimeters per year in the places where it blows most.

Under the conditions in which the Rayah Behera was found before the erection of the Katatbeh machines, the minister of public works estimated the volume of annual deposit to be removed, at 800,000 cubic meters, and in spite of this enormous quantity of work, the discharge at low water would hardly reach 16 cubic meters per second.

Katatbeh canal.—The Katatbeh canal, which forms a continuation of the Rayah Behera, has its inlet about 40 kilometers below the dam. Before the installation of the elevating-machines, which to-day supply this canal, the work at the head was formed by a bridge dam of masonry of five arches of 4 meter openings.

This canal has a mean width at its head of 20 meters at bottom; it is 123 kilometers in total length from its head to the Mahmoudieh canal, into which it empties; it follows at first the Rosetta arm until about the eightieth kilometer and turns then abruptly towards the west; it supplies all the canals with water which trend toward the boundary of the desert of the west, and which empty their waters into Lake Mariout. Several bridge-dams are established along the Katatbeh canal to facilitate the distribution of water.

The Katatbeh canal, which, as has been said above, was formerly only fed by its inlet, was afterward fed by the Rayah Behera at low water, for this later, the elevating-machines were substituted, but to-day in reality the water is provided partly at the inlet and partly by the Rayah Behera, and during flood it is placed to-day, as formerly, in direct communication with the Nile by the work at its head.

Mahmoudieh canal.—This canal has its head at a point situated very low on the Nile, at Atfeh, 56 kilometers from the mouth of the Rosetta arm. At this place the level of low water is often as low as 13 centimeters above the sea, and the level of the flood is 3.80 meters, the level of the soil being about 3 meters. The length of the canal being 77.50 kilometers from Atfeh to the sea at Alexandria, we see that the slope of the canal when it was fed directly by the Nile water was insignificant, at least during low water. Linant de Bellefonds claims that this canal was thus established with almost no slope, and that the head was placed thus near the mouth of the river because it was desired to allow the water in the canal a free course without locks, while with a more decided slope bridge-dams and locks would have been needed to facilitate watering and navigation. Naturally this solution produced all sorts of inconveniences, and especially very considerable deposits, whose removal became in time more difficult and costly.

To supply such a canal during low water and provide fresh water for Alexandria in a satisfactory manner they had transformed a large low area near Atfeh into a reservoir by means of

earthen dikes. This was filled during flood and emptied gradually into the canal during low-water season, the canal inlet being then closed. Since at this epoch there was no lock at this locality, they were always obliged to transfer freight from above and below the work at the head. In 1842 a double lock was built at Atfeh, one 12 meters wide, the other 8.50 meters wide. The apron of the Atfeh lock is held at the 1.37-meter mark and that of the Alexandria lock is held at 1.90-meter mark, a difference of only .53 centimeter between the two.

At this epoch the Mahmoudieh only received water during low water from the Katatbeh, whose inlet is 170 kilometers above. Formerly the summer crops were very little developed along the Mahmoudieh canal, and it was hardly necessary to irrigate in this region more than 2,000 hectares. It is no longer so to day; this canal waters almost 70,000 hectares and more than three hundred and thirty outlets are scattered along its banks.

To conform to these new conditions and supplement an insufficient supply obtained from the Katatbeh, since 1850, Said Pasha established at Atfeh elevating-machines capable of raising 800,000 meters of water in twenty-four hours to a height of 2.50 meters. These machines work nearly one hundred and fifty days yearly. During high water the supply is taken directly from the Nile.

In consequence of the maladministration of the country and the neglect of the agents of the Government, the canal lacked little of being again filled with mud, and in 1870 it was necessary to remove by contract 2,000,000 cubic meters of mud. These large deposits resulted in part from the lack of longitudinal slope and partly from the large deposits produced at the point of junction with the Katatbeh.

At present the type-profile of the Mahmoudieh canal has been fixed at 20 meters width at bottom, with slopes of 2 base to 1 vertical as a maximum, with a banquette of 4 meters, 50 centimeters above low water. The depth below the plane of low water was held at 2.60 meters, the level of high water reaching 4 meters. The level of the bottom being, at the head, 50 centimeters above the apron of the Atfeh lock, and that of the lower end being 69 centimeters above the apron of the Alexandria lock, the total slope was 34 centimeters; the pool of the Alexandria lock was 1.39 meters and that of the Atfeh lock was 1.50 meters at low water.

For the last five years, the discharge of the machines at Atfeh having been increased, the theoretical depth of water at low water is 2.90 meters, but it has rarely attained this level because it has not been possible, up to the present, to regulate the outlets established along the canal, and because individuals often consume water out of proportion to their needs.

The plan of the Mahmoudieh could not be more defective, and shows the condition under which it was built. According to Linant de Bellefonds, this canal was built by the men of the *corvée*, whose number went as high as 350,000, who came upon the ground and began to work before the plan was even staked out. Each contingent began thus to dig at the locality where it found itself, in a direction roughly indicated on the ground. Naturally the lines adopted by each gang of workmen formed a broken line, which it was necessary to bring together by numerous and sharp elbows. The canal also crosses low and marshy lands, in which the embankments were very difficult, notably at the crossing of Lake Aboukir, where for 10 to 12 kilometers it was necessary to sustain the banks by masonry walls; in addition, on leaving Atfeh, to avoid Lake Edkou, it was necessary to trend towards the south instead of directly towards Alexandria.

Under present conditions the Mahmoudieh canal requires each year from 200,000 to 300,000 cubic meters of dredging.

*Elevating-machines of Atfeh and Katatbeh.**—The elevating-machines, which serve for irrigation in the province of Behera can only be compared in importance with the magnificent establishments which are used for elevating the water of the great polders and drained lakes in Holland.

It was in 1880 that the Egyptian Government determined to establish these large plants for irrigation. This was not to be an isolated experiment, but a system which it was proposed to extend over a greater part of Lower Egypt, and which had for its first object the supply, during low water, of all the principal existing canals by means of machines established at their inlets, and as a result the suppression of canals of great depths. Although this method was costly, and

* See Plates XVI and XVII.

certainly more onerous than a system of irrigation based on the complete utilization of the great dam of the Delta, and the distribution of the water in the provinces of the east, center, and west by three great derivations from the dam, the Government was induced to study it and apply it, partly for many reasons due at the same time to the financial situation and the feeling of the country. In the first place, the work of the dam had fallen into discredit, and on the other hand the possibility of its completion had encountered many skeptics, and caused such an enterprise to become problematical; also the little confidence which could be placed in the official resources and spirit of perseverance of Egypt, overloaded by debt, rendered doubtful the proper execution of this work. It might in fact be doubted whether this country, under the existing conditions, could complete so considerable a work, comprising not only the completion of the dam but the digging or adaptation of the other watering canals and their connections with these great arteries, the construction of indispensable drainage canals, and all the accessory works, foreseen or unforeseen, which result from a complete change in the hydraulic regimen of a region. At this time people acquainted with the country, and among others Rousseau Pasha, under Secretary of State for Public Works, recoiling before the difficulties which a complete execution of such work met with, undertook the system of irrigation by machines, which had the advantage of doing away with the heavy work of dredging to great depths, which was necessary every year, at the inlets of the principal canals; the advantage of insuring quickly a normal discharge to the canals by giving to companies the privilege of the elevating-machines, paying only for the first outlay in a certain number of years; the advantage of changing as little as possible the actual arrangements for irrigation, so as not to alarm the farmers, who always have a great dread of any raising whatever of water, on account of the infiltration and saline alterations of the soil which follows. Moreover, it should be added that the financial resources of the ministry of public works did not permit, except for the three great canals of Ibrahimieh, Ismailieh, and Mahmoudieh, the execution of dredging by contract or with dredging-machines, and it was compelled for all these works, and even for deep dredging, to have recourse to the manual labor of the *corvée*, which was becoming very difficult to recruit under the influence of the more benignant and humane ideas introduced by Europeans into Egypt. Besides it was very desirable to give by the quickest methods the regular normal watering to the different provinces, doing away with the laborious work of dredging the deep canals.

The difficulties of maintenance were very great in the province of Behera on account of the length of the principal canals and the scarcity of labor; it was here that the first elevating plant was installed. It was proposed to erect new ones for the watering of the northern part of the province of Dakahlieh when the events of 1882 led to the intervention of England in the affairs of the country.

The English engineers, following the practice of irrigation in India, then took in hand the administration of this service in Egypt, and the new resources were placed in the hands of the ministry of public works, both for the execution of the new works and to allow the substitution of the contract system for the system of *corvée*. This made it possible to undertake a complete project for the utilization of the great dam and for abandoning, at least for the greater part of Lower Egypt, the system of irrigation by machines which is now confined to the province of Behera.

A contract was made May 11, 1881, with a company represented by Mr. Ed. Easton, an English engineer, to supply by means of steam-pumps the Mahmoudieh canal at Atfeh and the Katatbeh at its inlet. The undertaking comprised first, the extension and, if necessary, the transformation of the old plant, which had been established at Atfeh by Said Pasha to carry water to the Mahmoudieh during low water; second, the erection of a plant and its accessories at the mouth of the Katatbeh.

The principal agreements of this contract were as follows:

The water was to be raised from the Nile—

At Atfeh to a height of 2.90 meters above the level of the sea, or to a maximum height of 2.75 meters above the lowest stage of the Nile (the level of the neighboring land is 3 meters);

At Katatbeh to a level of 9.50 meters, or 3 meters at most above the low-water stage of the Nile (the level of the riparian lands being 13 meters).

The discharge of each of these establishments was to be 1,500,000 cubic meters in twenty-four hours.

In 1883 the company had not yet completed its work on account of the disappointments met with in the use of the machines of the Katatbeh. The Government then perceiving, after the suppression of the Rayah Behera and when all the water for the province would be furnished by the machines at Atfeh and Katatbeh alone, that a discharge of 3,000,000 cubic meters would not be sufficient, especially since the amount of cultivated ground had been much increased on the side of the desert, a new contract was entered into with the same company to place its elevating-machines in a condition to raise at Atfeh 2,500,000 cubic meters and at Katatbeh 2,500,000 cubic meters in twenty-four hours.

At Atfeh the plant has been working since 1885, but at the Katatbeh it was not until 1886 that the pumps were able to deliver regularly the required discharge.

The date of starting the pumps is fixed each year by the ministry of public works according to the level of the Nile water, but the normal dates stipulated in the contract are February 5 for the Mahmoudieh and April 15 for the Katatbeh.

A heavy fine, as high as 26,000 francs, can be imposed on the company for a total stoppage of one day of one of the establishments

The Egyptian Government pays the Society of Behera—

First. An annual fixed sum of 684,300 francs, representing the interest on the capital invested and the general expenses independent of the working of the machines.

Second. A sum of 723 francs per million cubic meters raised at Atfeh and 1,092 francs per million cubic meters raised at the Katatbeh.

In order to make comparison with other countries it must be understood that the price of coal delivered at the pumps was 40 francs per ton on the average at the time of signing the contracts. The society has the right of raising water for a period of thirty-five years. The Government has the right to buy back this concession on certain conditions at any time after the twentieth year.

Such are the general conditions under which the society furnishes water to the Mahmoudieh and Katatbeh canals. As soon as the concession was obtained in 1890 Mr. Easton immediately began the works of installation at Katatbeh as follows:

First. A feeder canal, 35 meters wide at the bottom, about 80 meters long, between the Nile and the plant.

Second. An inlet work formed of three masonry arches of 7-meter openings, closed by means of iron gates, whose apron is 1.50 meters below the lowest water of the Nile.

Third. A discharge canal, 20 meters wide at the bottom and 500 meters long, between the plant and the Katatbeh canal.

Fourth. A reservoir, between the inlet work and the discharge canal, containing the elevating-machines.

Fifth. The plant and its accessories.

The elevating-machines were composed originally of ten enormous sheet-iron Archimedian screws, 4 meters in diameter and 12 meters long. These ten screws, arranged parallel, were moved by a shaft 50 meters long, actuated at one of its extremities by a compound vertical engine of the marine type. This project, badly conceived, badly elaborated, and badly executed, gave deplorable results. From the first day the screws broke and the plant was stopped.

After several futile efforts to repair this disaster the society, finding itself obliged by its new contract to furnish a larger quantity of water than was at first expected, took radical measures and decided to change completely the adopted system, and gave the house of Forcat, of Saint-Ouen, an order for new machines, requiring them to use as much as possible the inlet and old foundation in the installation of the new plant.

The plant is composed now of five horizontal engines, each moving directly, without intermediate mechanism, centrifugal pumps with vertical shafts. The engines are steam-jacketed, compound, condensing; the cylinders are 1 meter in diameter, and the piston has a stroke of 1.80 meters. The vertical shaft has a horizontal crank on its upper end, the wrist receiving the action of the connecting-rod.

A fly-wheel weighing 22 tons is keyed to this shaft, which carries lower down the wing-wheel of the rotary pump. The toe for the vertical shaft is arranged outside of the water taken for the turbines.

The suction of the pumps is 2.10 meters in diameter and the wing-wheel measures 4 meters over all, having a height of 2 meters. The suction-pipe is bell-shaped and placed below the level of the water. The wing-wheel pushes the water towards the exterior into an annular receptacle which surrounds the wheel and is supported by three cast-iron pillars upon an apron. This annular ring is prolonged to the discharge-pipe, at first curved to the shape of a siphon, to preserve the priming, and then increasing in section in order to fit the masonry conduit which lets the water into the feeder canal.

When it is desired to start the machine, friction is produced on the toe of the vertical shaft and necessitates a special method of lubrication. This vertical shaft, about 8 meters long, carrying a crank, fly-wheel, wing-wheel, and the weight of the water raised, causes a pressure at the toe of about 50 tons. In order to diminish the friction, and to transmit the weight between the extremity of the shaft and its step plates, five disks are made use of, 220 millimeters in diameter, two of hardest steel and three of hard bronze, lenticular in form, with surfaces alternately concave and convex. The upper disk is made fast to the turning shaft and moves with it, the following only takes part of the motion, the third receives still less, and so on to the last, which is fixed to the step. These disks are inclosed in a cast-iron box filled with oil, but this did not permeate to the center of the disks and heated rapidly. To remedy this defect an arrangement invented by M. Vigrean, professor in the Central School of Arts and Manufactures, was employed. It consists in establishing around the pivot a continuous current of oil. The cold oil comes through the axis of the disks and drives out the hot oil into a tube, which descends to the Nile; here it is recooled in a worm and is raised by a pump to the roof of the establishment, whence it returns by its own weight to the pivot.

This system is now used for three of the machines. For the other two M. Forcat has adopted a similar arrangement for circulating the oil, but in this the movement is given the oil by a small rotary pump connected with the pivot itself; the oil is cooled in a refrigerator turning with the pivot, into which cold water is injected by a pump, also turning with the shaft. This method seems a little complicated.

These centrifugal machines are boldly conceived, but they have not been in use long enough to determine their advantages or defects.

These centrifugal machines work with a mean speed of thirty-five revolutions per minute and a maximum of 40 revolutions. They are capable of discharging 7 cubic meters per second.

To these five pumps, are added as a reserve, three of the large Archimedian screws originally used; these screws have been carefully strengthened. The upper ends of the axes are held by collars, and the lower rest in sockets; also the bodies of the screws are supported at their middle point by means of radial braces. Each of these screws can discharge 2 cubic meters per second. They are actuated by a compound vertical engine of the marine type.

The total capacity of the plant is, then, more than 40 cubic meters per second, or about 3,500,000 cubic meters in twenty-four hours; the total effective horse-power of the machine is 3,500.

The steam is furnished by a battery of eleven tubular boilers, three of which, furnished by the Creusot shops, have a heating surface of 190 square meters, and the other eight, of the Forcat pattern, have each a heating surface of 175 square meters.

At Atfeh the conditions were very different. In the first place, the height to be overcome was less; besides, it was necessary to use, as much as possible, the old plant. M. Boghos Pasha Nubar, a director of the contracting company, ordered the machines for this plant from M. Ferey d'Essonne.

At Atfeh the plant is composed of eight large Sagebien wheels, 3.60 meters wide and 10 meters in diameter, raising the water to a maximum height of about 2.60 meters, each having a possible discharge of 400,000 to 500,000 cubic meters in twenty-four hours. Four of these wheels are placed in the old government pump building. They are worked by the four old engines which formerly worked the Archimedian screws. These engines, with walking beams and vertical guides built by the English firm of Forester, have one cylinder; the steam system was modified and they were

changed to engines of the Wolf type by the addition of extra cylinders. Their performance was in this way much improved.

The other four wheels are arranged in another building and moved by compound engines of the marine type, which were originally set up at Katatneh to move the Archimedian screws.

Steam is furnished by a battery of ten tubular boilers, each with a heating surface of 190 square meters.

The greatest power which the plant has been able to develop is 1,250 horse-power in water raised.

At Atfeh the plant is located on the left bank of the Mahmoudieh canal at the height of the lock at the mouth.

The feeder canal, 170 meters long, is 30 meters wide at its mouth with an inlet work of two arches of 8 meters and one of 5 meters, closed by iron gates. The level of the apron of this work is at the 90-centimeter mark, below the sea.

The discharge canal, 90 meters long, is 26 meters wide at the bottom. It empties into the Mahmoudieh canal by a work crossing under the canal embankments, composed of five arches of 4 meters. The height of the canal bottom is 1.26 meters above the sea-level.

After the Rayah Behera was absolutely abolished and the province supplied solely by the machines of Atfeh and Katatbeh, it would very probably be necessary most frequently to begin working the machines before the normal dates, fixed by contract as February 5 and April 15 for each plant respectively; more especially since by the hermetical closing of the great dam the discharge of the Damietta arm has been diminished; besides, as the machines should work until the flood is sufficiently high, and as they hardly ever can be stopped on this account before the end of July, it is necessary to calculate on two hundred days' annual work at Atfeh and one hundred and fifty at the Katatbeh.

Under these conditions the irrigation of the provinces comes to about 1,400,000 francs. As the cultivable surface is 196,000 hectares, this gives an expenditure of 7 francs 10 centimes per hectare, not counting the necessary cleaning of the canals and strengthening of the dikes and other earth-work, which would amount to nearly two-thirds of the same sum. Thus we have an annual expenditure of 11.80 francs per hectare—a very considerable sum.

But, up to the present, the Rayah has always contributed in a certain measure to the irrigation of the province. Thus, according to official reports, in 1880, 1881, 1882, and 1883 the daily receipts of water for this region were estimated at 2,000,000 cubic meters at low water, which corresponds to a continuous discharge of 23 cubic meters per second. These receipts were divided as follows:

	Cubic meters.
Rayah Behera.....	1,300,000
Atfeh machines.....	700,000
Total.....	2,000,000

In 1884 the daily receipts were 4,500,000 cubic meters, divided thus:

	Cubic meters.
Machines of Katatbeh and Atfeh.....	2,500,000
Rayah Behera.....	1,500,000
Total.....	4,000,000

This corresponds to a continuous discharge of 46 cubic meters.

In 1885 the daily receipts were 4,350,000 cubic meters, divided as follows:

	Cubic meters.
Atfeh machines.....	700,000
Katatbeh machines.....	1,500,000
Rayah Behera.....	1,650,000
Total.....	3,850,000

In these amounts are not included the volumes elevated by the few individual machines which are still worked along the Nile.

In 1880, 1881, and 1882, including the dredging of the Mahmoudieh, the mean annual volume executed was estimated as 1,800,000 meters for the repair of the canals and dikes of the province

of Behera. This amounts to almost 10 cubic meters per cultivable hectare. This amount of earth-work having been for the most part executed by *corvée*, it is difficult to estimate its actual expense. To this expenditure it is necessary to add the amount paid by the Government for the elevation of 700,000 cubic meters of water daily at Atfeh, in order to obtain the total cost of irrigation per hectare.

With the present system of distributing water and repairing the canals by contract the annual expense for the repair of canals and dikes in Behera is placed at 1,250,000 francs; in addition, the mean sum paid in 1884 and 1885 to the Irrigation Society for raising water was 750,000 francs; therefore the total annual expenditure, under the conditions of 1884 and 1885, was 2,000,000 francs, or 10.20 francs per cultivable hectare. This is a high price compared with other provinces.

In 1884 and 1885 the almost hermetical closure of the great dam of the Delta, on the Rosetta arm, lowered considerably the level of the water on this branch. As a consequence, low water at Katatbeh was lower than it had ever been imagined before. It is necessary, to allow the pumps to be fed, to build below the inlet a temporary dam similar to those already mentioned for the provinces of the east. This dam of earth, sacks, rough brick and stone, raised the level of the water 50 centimeters; which was sufficient.

Moreover, in 1884, the sea-water, owing to this diminution of discharge, reached as high up as Atfeh, so that the pumps on several occasions sent salt water to Alexandria and the city of Rosetta, and the entire cultivable territory comprised between Rosetta and Atfeh was deprived of fresh water. To remedy this inconvenience there was built across the Nile, below Rosetta, an earthen dike 430 meters long, with a channel cut through it 70 meters wide, bounded on both sides by pile-dikes. The depth of the bed at this point varied from 2 to 5 meters. The rise thus obtained was sufficient to prevent the sea-water from backing up the river.

Since then a special canal has been constructed from the Mahmoudieh, near Atfeh, following the Nile dikes as far as Rosetta, about 30 kilometers long, designed on the one hand to assure a supply of fresh water for this city, and on the other to irrigate the low lands along its course. But since the great dam of the Rosetta arm has been kept closed during low water, and the Rayah Behera has not been put in condition to supply by itself the province without recourse to the Atfeh and Katatbeh pumps, it has been necessary every year to rebuild at great expense the temporary works across the Nile.

To obtain the cost of restoring irrigation to the province of Behera during the period of transformation, when neither the Rayah nor pumps can be fully utilized, it is necessary to add to the amounts already mentioned above the cost of building these temporary works, or 340,000 francs, which give an addition of 1.50 francs per cultivated hectare.

CHAPTER V.

CONSTRUCTION AND REPAIRS OF CANALS, DIKES, AND WORKS OF SKILL.

GENERAL CONSIDERATIONS—CORVÉE—DRY EARTH WORK—DREDGING—WORKS OF SKILL—EXPENSE OF REPAIRS— WORK EXECUTED BY INDIVIDUALS.

I. GENERAL CONSIDERATIONS.

When we consider the condition of Egypt, where all works of skill are built on alluvial soil, very compressible, where all the canals are dug in the mud, where all the dikes are formed of soil easily degraded, where the fertilizing water carries with it every year a great quantity of material in suspension; finally, where the Nile flows in a bed naturally movable, it is readily seen how important to the prosperity of the country is the continual and regular repair of all the irrigation works, and at the same time how costly this repair must be. For the execution of all these works there was needed in the hands of the Government a powerful instrument, independent of financial resources and revenue, more or less difficult to collect. This instrument was found in the *corvée*; that is to say, the obligation imposed on all the inhabitants of the country to labor gratuitously on the works designed to insure the irrigation of the land. Thus each year large gangs of unpaid laborers were drafted from their villages to strengthen and clean out the dikes and canals. Naturally such removal of men was not accomplished without cruelty and arbitrary action, and the lash was the great auxiliary of the functionaries charged with assembling the *corvée* for work. Under the influence of more benignant methods and progressive ideas, which Europeans have introduced into Egypt, violent means are tending to fall into desuetude, the recruitment of the *corvée* has become each year more difficult, and it has become imperative to reduce the amount of forced labor imposed on the farmer. This has been accomplished either by applying special revenues to the construction of certain works of skill, intended to diminish the annual work of repair, or by supplementing with paid labor the insufficient work of the *corvée*. Moreover, since the general introduction of summer crops and the extension of the net-work of deep canals, the most important part of the labor of dredging has become too heavy to be accomplished by the method practiced in the *corvée*; therefore it is confined as much as possible to earth-work, which requires the least removal of the peasants and which can be executed dry. Other earth-work, as far as official recourse allows, is done mechanically by means of dredges or executed under contract by paid labor.

II. CORVÉE.

Although the system of the *corvée* is properly repugnant to our modern ideas, it is no less true, if we consider the state of Egypt at the time when cultivation by inundation basins prevailed throughout the whole land, that the use of forced labor was in a certain degree legitimate, and that it is still so in the regions where this method of watering still exists. Linant de Bellefonds stated this correctly in his work already referred to, which contains so much valuable information as to all the public works of Egypt.

A basin, in fact, constitutes a great farm, to whose prosperity all those who own a part should contribute; and as there is generally only a single crop a year, which only lasts five or six months,

the peasants, after the harvest, should at least employ themselves in clearing the canals and strengthening the dikes. Each owner being able to cultivate his fields only when the whole basin is put in condition to receive and hold the inundation water, it is then very natural that they all should join to execute together during the season of repose, the work of the dikes, the construction of drains, and the clearing out of canals which are of general benefit.

An absolute power could greatly abuse the facility which a *corvée*, without control, presents for great works. This, in fact, is what has already happened in Egypt, notably when Mehemet Ali began the irrigation canals which to-day cut up the country. *Corvées* of more than 300,000 men were then seen, drafted from every part of Egypt, digging the Mahmoudieh canal, which was of very little importance to cultivation, and which was especially designed for the benefit of the city of Alexandria. At this time the labor demanded annually from the *corvée* corresponded to the employment of 450,000 laborers for four months.

Most of the canals were thus constructed by unpaid people, who received no benefit from them. Afterwards, in the same way, to clear out the Rayah Behera and the Katatbeh Canal, which water the provinces of Behera only, it was necessary to bring every year more than 15,000 men from other provinces; also, under the Khedive Ismail Pasha, the great Ibrahimieh canal, which benefited almost solely the immense vice-regal possessions, was dug by contingents of the whole *corvée*, and the principal canals derived from it are still repaired by the inhabitants of the province of Siout, to whom it is of no benefit.

Also, when we consider the great development of the net-work of canals which afford fertility to the land of Egypt, while doing justice to the intelligence and energy of the sovereigns who have pushed the execution of the gigantic labor, we can not avoid referring to the amount of fatigue and misery and to the excess of rigor and tyranny at whose cost the present generation has inherited from their fathers such a method of irrigation.

The despotism which has prevailed in the allotment of the labor of constructing canals among the *corvée* also obtained in the repair of these works, and it often happened that the large proprietors were exempt from sending their laborers to the *corvée* for the cleaning out of the canals necessary for their own crops, while the poor fellahs were driven to onerous labors whose results were of no benefit whatever to their land.

On the other hand, the *corvée* was often diverted from the purpose it was specially intended for, and used for the construction of railroads, for a part of the Suez Canal, dry-docks, and in general all kinds of public works, sometimes also to private works to the great profit of the sheiks, pashas, and agents of the Government.

The *corvée* under such circumstances can be only odious to the country. Besides, although it is indispensable in certain exceptional and imperative cases, especially in the regions of irrigation, and as a means of utilizing the vital energy of the country, it is only suitable to countries whose administration is bad and whose treasury is empty.

The Khedive's decree of 25th January, 1881, determined in a general manner the works which are now placed in charge of the *corvée*.

According to this decree, the works relating to irrigation are divided into three categories: Those charged to the state, that is to say, whose expenses are charged to the resources of Egypt; those charged to the population in general, that is, whose execution must be done by the *corvée*, and those charged to the owners of the land benefited.

The works charged to the state are as follows:

Labor in reference to the works of skill, which concern one or more provinces, existing or to be constructed on the Nile and its branches, on the dikes, on the principal canals, on the dikes of the basins of Upper Egypt, and other dikes of general interest.

The dredging which is done by means of dredging-machines, in which are comprised all the expenses of plant, working, and repair. In 1881 the dredging-machines were hardly used, except for the three great canals of Ibrahimieh, Ismailieh and Mahmoudieh.

The supply and transportation of material, such as stone, wood, etc., required for the general good, and for the preservation of dikes and works, and for closing dams and inlets of the canals.

The works charged to the population in general are as follows :

Earth-work, filling and excavating and hand dredging, which benefit one or more provinces, the villages of one or more districts. [The districts correspond almost to French cantons.]

Guarding the dikes and works during the Nile flood.

Handling and preparing the materials destined for the preservation of dikes, canals, works of skill, and for closing the dams and inlets.

The works charged to those interested are :

Earth-work, watching, closing dams and inlets, which benefit alone one or two villages or special proprietors.

The labor which concerns the works of skill, constructed or to be constructed, on the canals or dikes, benefiting either villages of one or more districts, or one village or special proprietor.

The works incumbent on the *corvée* are those which are designated above as being charged to the population in general, and they are thus perfectly defined. It may be said except in what concerns the construction and repair of works of skill, and except for the last ramifications of the canals, the *corvée* should furnish, according to the regulating decree of January, 1881, all the manual labor for the construction, repair, and watching of canals and dikes. These requirements have been much modified and much of the construction of dikes and canals, and even works of repair, has been done for cash by contractors.

The methods of executing work by *corvée* are most primitive.

For earth-work the only tools which the *corvée* use are the *fass*, a kind of iron hoe, very large, and with a short handle, and the *couffin*, a kind of cylindrical basket woven from the stems of palms. The *fass* serves to loosen the earth, and the *couffin* to carry it. The ordinary *couffin* is furnished with two handles of palm rope, and it holds practically from 10 to 15 liters, although it has a capacity of 20 liters. These *couffins* when repaired are bound and re-enforced with ropes of palm. The ordinary *couffin* can be used, before becoming worthless, to transport about 40 cubic meters of dry earth and 30 cubic meters of wet earth, and the repaired *couffins* may be re-enforced to transport as much as 50 or 60 cubic meters of earth, either dry or wet. But most frequently, and especially when the *couffins* are employed by the *corvée*, they are completely used up after having transported from 4 to 5 cubic meters. The price of a *couffin* is 35 to 40 centimes; the re-enforced *couffins* cost 50 to 60 centimes.

To work deep canals, that is, the feeder canals, basins and canals designed solely to carry flood water, they wait until they are dry. The men of the *corvée* are then arranged along the canals and divided into diggers and carriers; the latter are generally children. The man with his *fass* hoes up the bed of the canal and puts the earth into the *couffin* which the child raises up by its two handles and carries it upon his head to the embankment and places the deposit. In general the bottom of the canals are formed of mud stiff and cracked; when the deposits to be removed are composed of sand, the hand often replaces the *fass* to move the soil and fill the *couffin*. These labors can be executed at any time whatever in the interval comprised between the two floods. It is always so arranged that they occur in the period of repose for the peasant in the intervals of cultivation.

For the deep canals the work is very heavy. In the first place, the banks are very high; this increases very much the length and difficulty of haul; also, frequently in the vicinity of the heads of the great canals, the height of the embankments above the bottom extend 10 meters. In the second place, since they are obliged to execute the carrying when the water is already low in order to facilitate drying, as at this moment the crops still require water, the time allowed for drying and making embankments is very limited. It is not then possible to obtain, in the lower pools, by drainage or by simple evaporation a complete drying of the mud; besides at such depths below the soil it is often difficult even with time to completely get rid of the water. Under these conditions the unhappy peasant of the *corvée*, almost naked, in this miry soil at the bottom of great trenches, whose banks are heated by the rays of a burning sun, fills, sometimes with a *fass* and sometimes with his hands, the *couffins*, which are hoisted along the slope of the canals slowly and with great toil by his companions in labor, to the summit of the embankment. Such labors, which are to-day almost abolished for the *corvée*, can only be executed by a severe use of the lash, and

even with these barbarous methods it is almost impossible to have the earth carried as far as the top of the dikes; it is deposited merely at the foot of the embankment or along the slope a little above the level of low water—a true labor of Sisyphus, because each year this same earth slides to the bottom of the bed in high water and has to be removed with the same trouble and fatigue.

In certain cases, also, the needs of irrigation do not allow them to wait until the bed is almost dry to commence clearing. Then the men of the *corvée*, immersed in the water up to their middle, try to draw from the bottom of the canal with their hands most of the sediment, which they pass one to the other across the slope. This is work which a progressive government evidently should not demand by forced and gratuitous labor.

The deep canals are cleared by the *corvée* before mean water, so that they can carry their normal discharge during lowest water. At times it is impossible, on account of the requirements of the crops, to stop the discharge of the canal long enough to finish at one time the total clearing; so it is done at two periods, the first before the time of sowing and the second at the time of lowest water.

Besides the canals, the *corvée* has also to execute the repair of the dikes.

For the dikes of the Nile, the work consists especially in the repair of the slopes, the dikes, and repairing and filling the cuts made for irrigation during low water. The earth designed for this work is always taken from a little distance from the foot of the dike and all along the part repaired; this is then simple dry earth-work which is done with the *fass* and *couffin*.

The labor of repairing the dikes of the basins is of the same nature. It comprises mere slope repairs of the dikes at points where the regulating works and outlets consist merely of breaches in the body of the embankment itself to drain the inundation water into either the lower basin or into the Nile. The amount alone of these breaches has been 40,000 to 50,000 cubic meters. As the flow of waters through the breach produces excavations which would be too considerable to fill, they construct a dike above this excavation and connect the new dike with the old by curves, paying no attention to the regularity of their plan.

The works of the dikes are executed at the same time as the works of the clearing of shallow canals.

In case the *corvée* is called out to construct new dikes and canals, the method of executing the work is the same as has just been described; however, in concordance with present ideas, the *corvée* is almost exclusively devoted to the works of repair.

Even during the period of the flood the *corvée* does not remain idle; as soon as the water reaches a certain height contingents are called out for guarding the dikes. The men are then stationed along the dikes of the Nile and the basins to watch carefully the effect of the water, protected by small huts of reeds, night and day they are called out to help if a spring or a leak shows itself in the portion of the work confided to their care.

The north slopes of the basins require especially very particular attention; in fact, as has already been seen, the north wind prevails during the inundation, and the water of the basins under the influence of this wind forms small waves, which break against the dikes and abraid them without cessation. Thus the watchmen are obliged to watch with care that the protection of rushes and reeds which is placed along the slope is maintained in good condition, and immediately replaced in case of removal.

The watching of the Nile dikes commences about the 1st of August and ends about the end of September or the 1st of October, and for the basin dikes it lasts from the moment of filling to the moment of emptying.

Another portion of the contingents of the *corvée*, during flood, is called out to watch and maneuver the gates at the regulating works; they are charged especially to attend to breaks which may be produced in the shutters which close the dam openings and to raise and put in place these shutters, either to regulate the level in the basins of inundation or to obtain a suitable height of water in the canals of irrigation. The maneuvering of the shutters of the gates, which are in general vertical needles, is accomplished by means of cranes and tackle, or by means of movable winches.

Finally, when the works of skill are injured, or when their banks are attacked by the water, or one of the dikes of the Nile or canals is threatened, the Government brings stone, which the *corvée* use either for riprap or for spurs.

Such is the method by which the *corvée* executes throughout the whole year the works of different kinds which are allotted to them.

Every year after the flood the agents of the Government prepare the allotment of the labor incumbent on the *corvée*, and submit it about the middle of the month of December to the agricultural council, of whom there are six for the whole of Egypt; three in Lower Egypt, and three in Upper Egypt. These councils, in which the notables of the region, under the presidency of an administrator of the province, discuss the allotments presented, classify the work into works of general interest—that is to say, of interest to one or more provinces—and works of communal interest—that is to say, interesting villages of one or more districts; they apportion these then among the population of the provinces and districts, and finally the number of men to be raised for their execution, and the number of days which the contingents will remain on the works. The decisions are submitted for the approbation of superior authority.

It is always a very delicate task to assign equitably the burden of the *corvée*. Thus the population nearest the inlet of the canals—that is to say, the part whose repair is most onerous—are not always those who profit most by the water of the canals. But, nevertheless, to avoid great displacement of men as much as possible, they are charged with the dredging; this is the case, for example, in the province of Galoubieh, where are the inlets of numerous canals which water the Charkieh, and in the Menoufieh, where are all the heads of the canals of Garbieh. In other cases, as in the province of Behera, the population is not sufficient for the execution of the work. A few years ago recourse was had to the contingents of other provinces to insure the clearing the Rayah Behera.

The works of repair begin about the 15th of January and end in July; they are less during the period of winter crops, and in Upper Egypt they are completely stopped at this time; the work is done during two intervals, from January to March and from June to August.

For the work of guarding the dikes the councils of the provinces meet in the month of July. A part of the contingent called out come to their posts on the 1st of August and the rest on the 1st of September, and the entire contingent remains on guard until the danger of rupture to the dikes is passed.

When once the work is thus determined and when the time arrives to begin it, the men of the village are called to their places by the administrative authority of the province. Under the direction of engineers they are conducted by the chiefs of villages to their camps. They camp at these places until the completion of the work; often also, when the places to which they are assigned are far from the village in which they live and if their stay is to be a long one, their wives and children follow their steps, and true wandering hordes are thus established along the canals and dikes to be repaired. In such cases, after they have arrived, the Government furnishes tools and provisions. Such a displacement of population causes for some months each year great hardships in the lives of the peasants, and is for them a source of considerable expense which it is difficult to estimate, but which increases in a great measure the cost of the profit, already high without this, of forced labor.

In a general way payment in kind is due in Egypt from all the able male inhabitants between the ages of fifteen and fifty years, with the exception of the inhabitants of cities who do not possess land, and of some other classes, as the Ulemas and the Bedouins. These latter, charged especially with the guarding of the frontiers of Egypt all along the desert, are in fact exempt both from regular military service and from the *corvée*. They own, nevertheless, great quantities of cultivable land in the different provinces.

According to the last census, it is calculated the male population between the ages of fifteen and fifty years make up about 43 per cent. of the male population of the villages.

In fact, in practice this rule has many exceptions, and the burden of the *corvée*, instead of being equitably divided amongst the population, is borne everywhere by the simple peasant and small farmers. The pashas, the intendant of church property, and the rich farmers, themselves long

exempt from the duties of the *corvée*, use their influence to free their workmen from this tax. Thus in the district north of the Delta, the district of Kafr-Cheik, which contains 60,000 hectares, 22,000 hectares contribute in no manner whatever to the *corvée*. Of the other 38,000, 22,000 profiting by the privilege of escaping under the conditions which are indicated above, all the weight of forced labor falls on the 16,000 hectares. This charge is very heavy, because the 3,500 inhabitants who people the 16,000 hectares must furnish eight hundred men for one hundred and eighty days. In the entire province of Behera, which represents 196,000 hectares, during late years they have never been able to bring together more than three thousand men. This is because this province is almost entirely occupied by large native farmers, by the Bedouins, and the European proprietors who hide themselves behind treaty stipulations to avoid contribution in kind.

If we compare the census of 1848, which served recently as a basis for recruiting the *corvée*, with the census of 1882, it is seen that for the six provinces of Lower Egypt the number of corvéeable men has diminished in a great degree. In this period of thirty-four years it has been reduced from 634,000 to 376,029. This diminution is due without doubt in a great part to the increase of population of the cities, and perhaps also to the want of accuracy in the census, but it shows quite plainly that in all this interval of time the data for recruiting the contingents was not exact, consequently it was easy to escape the duty of the *corvée*.

It was admitted formerly that the execution of irrigation work required the calling out of one-fourth of the male population, as given in the census of 1848, during forty-five days; then later they preferred to call out one-eighth of the population for ninety days. It is considered generally that in Lower Egypt the work is equitably distributed when four men are furnished by each 21 hectares. The table below shows the distribution and duration of labor and number of men called in 1879 in each province, according to the official allotment of the ministry of public works, an allotment based on information which can not be considered as absolutely correct and which gives amounts somewhat exaggerated.

Provinces.	Number.		Amount executed.
	Days.	Men.	
			<i>Cubic meters.</i>
Dakaliéh	180	5,737	3,153,548
Charkieh	180	4,079	1,261,365
Galonbleh	180	2,341	1,541,114
Garbieh	180	6,845	3,562,164
Memoufieh	180	9,446	2,680,843
Behera	180	2,703	606,001
Gulzeh	180	6,168	902,272
Fayoum	105	1,819	454,335
Beni-Souef	113	4,502	573,119
Minieh	101	11,186	2,516,491
Assiout	109	13,160	4,485,923
Guirgneh	150	30,038	3,039,830
Keneh	150	17,536	2,981,606
Keneh	150	3,552	1,058,101
Mean of days and totals	152	119,312	23,829,599

At this epoch certain proprietors had not yet been authorized to buy themselves off from the *corvée* by the payment of a certain sum of money. They had not yet begun to substitute for forced labor the system of paid labor and contracts. These 29,000,000 cubic meters represented then the annual work of the *corvée*, executed by nearly 120,000 men, working on an average of one hundred and fifty-two days; this corresponds to 181,000 men working for one hundred days.

In 1885, the epoch when many improvements had been introduced by the English engineers of the irrigation service into the supplying of canals and the distribution of water, and when the

system of contract for repairs was already applied, the burden of the *corvée* had been very notably decreased, as is indicated in the following table:

Provinces.	Number.		Amount executed.
	Days.	Men.	
			<i>Cubic meters.</i>
Dakaliéh	210	7,941	1,868,911
Charkieh	195	6,425	937,689
Galonieh	195	3,109	557,689
Garbieh	} <i>Corvée suppressed, all work being done by contract.</i>		
Menoufiéh			
Behera	165	4,140	499,107
Guisseh	110	4,953	930,256
Fayoum	60	3,433	400,096
Beni-Souef	145	5,700	1,516,721
Minieh	95	9,441	2,852,316
Assiout	105	14,491	4,125,670
Guirguéh	105	17,852	3,733,846
Keneh	114	9,774	2,593,925
Keneh	148	3,888	952,316
Mean of days and totals	117	91,146	20,968,493

The amount required of the *corvée* is here reduced to 21,000,000 cubic meters; it represents the work of 160,000 men for one hundred days.

In 1886 the earth-work done by the *corvée* was still more decreased in amount in consequence of official arrangements which permitted the diminution of the amount allotted to gratuitous obligatory labor.

The amount exacted per man of the *corvée* per day amounts on an average to about 1.8 cubic meters. Generally, in calculating the number of men necessary for a certain work, it is estimated that one man can accomplish in one day 2.3 cubic meters of earth-work for the repair of shallow canals and dikes and 1.35 cubic meters for cleaning deep canals. These results would not be had if it was certain that the earth-work would be actually executed according to the direction of the engineers, that the dredging was well done to the bottom, the dikes and the slopes well regulated; but this is not the case, and it is necessary to add to the estimated cost of the whole in consequence of the disturbance which results to the country by considerable displacement of inhabitants, diverted from their ordinary labor for nearly three months yearly.

The difficulty of forcing the large proprietors to obey the communal law; the impossibility of obtaining by the *corvée* the proper and regular cleaning of the deep canals; the necessity, recognized for a long time in a humanitarian point of view, of gradually abolishing the *corvée*, at least for the heaviest work, and consequently the obligation of the Government as to financial resources which would permit it to execute certain works of repair for cash—all these reasons led the Egyptian Government, about 1880, to determine whether it would not be able to authorize the *corvée* to buy itself off under certain conditions. It was resolved at first to allow this ransom to everybody indiscriminately, but it was very soon feared that the hands would be wanting which were necessary for certain works, and in the decree of the 25th of January, 1881, it was stipulated in the first place that each individual who was obliged to contribute in kind could be exempted by furnishing a substitute; and in the second place, that only certain classes would be allowed to ransom themselves by the payment of a sum of money. These were as follows: The inhabitants comprised in the special domains conceded to private parties with exemption from taxes, and not counted in the villages in the census of 1848; the Bedouins, a class of proprietors to whom Mehemet Ali had granted special privileges to attach them to Egypt and the soil, and to stop their exactions and brigandage; the inhabitants of the villages needed for the crops of certain large properties which the state farms itself. The privilege of ransom for these latter were limited to Lower Egypt.

In the villages where the cultivation of rice predominates contribution in kind remains obligatory, according to the same decree, but each man of these villages was only required to do half

the work imposed on the inhabitants of other villages. This privilege was doubtless created because the attention given to the cultivation of rice is much more exacting and more continuous than for other crops.

The tax of ransom was fixed at 31.10 francs per man in Lower Egypt and 20.70 francs in Upper Egypt. In 1880 the tariff was fixed at 15.50 francs for the whole of Egypt.

The money derived by the ransom from contribution in kind was set aside to be solely employed for works having for their object the reduction or abolition of the *corvée*.

The ransom from the *corvée* from these data has given for the five years from 1880 to 1884 the total sum of 5,126,000 francs, or an annual mean of 1,032,200 francs, distributed very unequally between Upper and Lower Egypt. Thus in 1883, in a total receipt of 883,350 francs for the whole of Egypt, Upper Egypt only furnished 55,250 francs, the privilege of ransom being so much less extended in this region, and besides the labor of the *corvée* here being in general, especially in the provinces of the south, a lighter charge for the population than in Lower Egypt.

In 1885, on account of the greater and greater difficulties presented in the recruitment of the *corvée*, the tax of ransom was still further diminished; it was reduced to 7.80 francs per man in Lower Egypt, and in the region of the Ibrahimieh to 3.90 francs for the rice fields and to 5.20 francs in Upper Egypt. But the resources thus produced were insufficient at many points and the Government was obliged to add to its budget the sum of more than 600,000 francs to complete the work of the *corvée*.

The Government is now occupied in decreasing in a still greater measure the charge imposed on forced labor. It is calculated now that the labors incumbent on the *corvée*, according to the decree of 1881, for the repair and watching of the dikes and canals, represent an annual sum of about 12,000,000 francs, which corresponds nearly to a total volume of from 18,000,000 to 20,000,000 meters of earth-work. In 1886 the Egyptian Government devoted in its budget the sum of 6,500,000 francs to the execution by contract of a part of these works; the *corvée* only remained charged with the surplus. The *corvée* was thus free from the heaviest work.

III. DRY EARTH-WORK.

In the whole of Egypt dry earth-work, whether done by forced labor or contract, is executed in the same way with the two tools which have already been described above—the *fass*, to dig the earth, and the *couffin*, to transport it. It is rarely that the moving of the earth is otherwise than in transverse profile; the embankments are generally executed by means of borrow pits which border the embankments to be raised; it is not then necessary to carry for any distance along the embankment. In the rare case where a carry is required of more than 100 meters the employment of men as carriers becomes too costly and they substitute the donkey or camel.

From each side of the pack-saddle of the animal hang baskets of woven palms of the form of a truncated cone, whose bottom, moving about a kind of hinge of palm cord, in the manner of a valve, can be held firm by means of a cord and a wooden pin. Each basket is 80 to 90 centimeters high and 60 to 70 centimeters wide at its mouth; it contains about 70 liters. These baskets are filled by means of ordinary *couffins*; to empty them it is sufficient to open the bottom. The camel is obliged to kneel for the load, but remains standing to discharge it. They frequently substitute wooden boxes for the woven baskets when the camels are employed for the transportation of the earth.

In Egypt the peasant is a natural digger; nevertheless for heavy work and for contracts lasting a long time they prefer the men of Upper Egypt; they are known by the name of Saidiens. The diggers are paid generally 1 franc to 1.25 francs, the children from 50 to 75 centimes, for a day's work.

Frequently in the camps the workmen join in bodies and take small tasks of from 5 to 10 cubic meters. The price for a day's work of a camel is 5 francs, including the driver.

This work is paid for at the rate of from 30 centimes to 1.50 francs per cubic meter, according to whether it is ordinary earth-work or the work is rendered more difficult by the presence of water or moisture. In the case of cleaning deep canals the administration manages the work in such a manner as to prevent water entering the level to be cleared out, and to facilitate the drain-

age of the water which they contain. It is a part of the contract to complete the drying as may be most suitable to the progress of the work. In each province there is let out in a single contract, with one price per cubic meter of embankment, most of the earth-work of repair required for the year, at least that which can be done dry. Heavy penalties are exacted as a guaranty for this work, whose completion in a certain time is a vital necessity for the crops.

They have hesitated for a long time giving the contractors the repair of the canals on account of the known difficulties which the assembling of the *corvée* presents every year. Indeed, it was thought that they would fail in their engagement in consequence of the obstacles met with in obtaining workmen; but these fears have not been realized, and the contracts for repairs have permitted the relief in part of the *corvée* and the execution of the clearing-out work at leisure without the necessity of hastening the work, and in a measure sparing the population a prolonged displacement.

IV. DREDGING.

The three canals of Ibrahimieh, Ismailieh, and Mahmoudieh are the only ones which for some years have been regularly repaired by means of dredges; every year some dredging is done at certain points on the Nile near the mouths of some large canals. Until 1884, the Government executed these works as a tax with a plant belonging to it. At this epoch a contractor was charged with dredging the Ibrahimieh for some years with a plant of the Government; the repair of the Mahmoudieh was treated in the same way by another contractor. Finally, in 1885, in order to relieve the *corvée*, they gave up to certain contractors the general execution by means of dredges of the clearing of the principal canals of Lower Egypt for the period of eight years. These contractors were allowed to use in part their own plant and in part the plant of the Government; the repair of the Ismailieh canal was comprised in one of these last two contracts. All the dredging of the canals is now done by contract, the Government having entirely given up the execution as a tax of works of this nature.

The dredging plant of the Egyptian Government is composed of the machines bought originally from the contractors of the Suez and Ismailieh canals. The type of these machines is known; a very complete description of them is found in many technical treatises; some of them have a long discharge, others are made to discharge the earth into scows or steam barges. This plant is now old and much used and requires considerable outlay for repair and maintenance. To replace two of these old dredges which became useless the Egyptian Government ordered in 1884, in England, two new powerful machines intended for the repair of the Ibrahimieh canal, and which are of this general description:

The hull is of iron; it is 30.20 meters long, 8.10 wide, and draws 1.80 meters of water.

The dredge has a single frame at one end, and a chain of buckets working in an opening 13.50 long by 1.70 meters wide cut in the axis of the hull. This machine is worked by a compound vertical engine with coupled cylinders of 60 nominal horse-power. The engine works the upper drum of the frame, without the use of a vertical shaft, by means of direct spur gearing, with a starting level on the bridge and a friction brake. The boilers are two in number; they are tubular and internally fired.

The length of the frame is 23 meters, measured from the upper axis of suspension to the lower drum; the upper axis is not rigidly connected to the axis of the lower drum; it is so arranged that the frame may be lowered to dredge to a depth of 8 meters, and raised so that the lower drum may be above the water.

A special steam-engine works the machine for raising the frame, and a quadruple steam windlass, placed on the bridge, serves to move the dredge from point to point.

The drums have four sides, and carry at the corners four tempered, square cast-steel bars, and the chain of buckets is so arranged as to be supported not only by the bars but also by the body of the drum itself, covered with steel plates.

The buckets hold 450 litres; they are of soft steel and armed with beaks of hardened steel; the articulation pins are of hardened steel, and the links are also furnished with steel bushing. Each dredge can raise about 150 cubic meters per hour.

Each of these dredges cost 425,000 francs, delivered in Egypt.

In the dredges employed in Egypt it is important that the buckets should have a form sufficiently flaring to prevent the mud from sticking to the sides.

It has been shown above that the amounts to be dredged annually are:

	Cubic meters.
For the Ibrahimieh	730,000 to 1,150,000
For the Ismailieh	150,000 to 300,000
For the Mahmoudieh	200,000 to 300,000

The plant required to excavate such an amount of dredging is necessarily large; thus the Egyptian Government owns for dredging the Ibrahimieh alone ten dredges in a more or less good condition, twelve steam-lighters, three barges, and two steam-launches.

For this canal the dredging is done by three different methods, according to the locality. Near the mouth the dredges dump the soil into steam-lighters, which take it to the Nile. Farther off, in order to avoid carrying the spoil a long distance, they employ dredges with long delivery, but as the banks are very high, and also the width of the bed too great, they are satisfied to dig a ditch in the middle of the channel, on the edges of which the spoil is dumped. The method is very vicious, because the current, in a short time, redeposits necessarily on the bottom the spoil dumped on the edges; therefore it is very necessary to abolish this method of work.

Finally, below Derout, they also employ dredges with long delivery, but they are careful to excavate, in the embankment itself, at a level above the water, a longitudinal ditch 6 or 8 meters wide, into which the pipe empties the spoil. Every year, before beginning to dredge, they are obliged to dig this ditch along a part of the canal to be dredged, and to carry behind the embankment the spoil of the preceding year. The development which this accumulation of yearly spoil gives to the dikes here and for almost all the canals of Egypt is one of the grave inconveniences of the system of dredging employed; the dikes attain rapidly considerable heights, which interfere with the deposits of the later dredging and render the work more and more costly and difficult, and also cover large areas of good land thus rendered unproductive.

On the Mahmoudieh and Ismailieh canals they operate the same as on the Ibrahimieh, with dredges and barges near the mouths; in the Mahmoudieh canal the dredging for the first 10 kilometers is done in this manner; farther on they are dredged with chutes and ditches dug on the banks. The contractor for the repair of the Mahmoudieh has used advantageously, in the middle portion of the canal, dredges dumping into barges, whence a centrifugal pump raises the spoil and throws it by means of pipes on the neighboring lands; here the spoil is used either to grade the land or to fill up the marshy portion of the ground.

The dredging by contract of the Ibrahimieh and Mahmoudieh canals has succeeded very well, but up to the present the two general contracts for dredging in Lower Egypt have not given very good results, and it may be said that machines capable of economically dredging the unimportant canals do not yet exist in this country. One of the two contracts was for an annual maximum of 600,000 cubic meters, to be taken from the principal canals of the province of Behera, with the plant belonging to the Government; the other contract was for the provinces of the east, and comprised two periods—the first of three years, during which the contractors agreed to dredge yearly 1,500,000 cubic meters, and the second of eight years, during which the annual amount was reduced to 500,000 cubic meters. This last contractor, except on the Ismailieh canal, for which he was authorized to use gratuitously the plant belonging to the Government, was to furnish, himself, the necessary plant for other dredging.

These two contracts have only been in force for one year; it is therefore difficult to estimate yet their ultimate effect.

In 1881 and 1882, the epoch in which dredging was performed as a tax by the ministry of public works, the mean cost of these works at the amounts below, which comprise the expense of manual labor, expenditure of material, maintenance, digging ditches for dredges of long delivery, and *personnel*, but do not include the deterioration of plant, are as follows:

For the Mahmoudieh Canal..	1.15 francs per cubic meter.
For the Ibrahimieh Canal....	1.25 francs per cubic meter.
For the Ismailieh Canal	1.20 francs per cubic meter.

At present the Government pays the contractor for dredging the Ibrahimieh 1.17 francs per cubic meter, and lends him gratuitously its plant, charging him with its maintenance. For dredg-

ing in the province of Behera, with plant loaned under the same conditions, the price was fixed at 97 centimes per cubic meter.

For the provinces of the east the price agreed to by the contractor is 95 centimes for the first three years, and 90 for the following five years. These prices are very high.

V. WORKS OF SKILL.

There is little to be said on the subject of the construction and maintenance of the works of skill.

These works consist almost entirely of inlet works, regulating works, locks, and waste weirs.

Most frequently the foundations are formed by an apron of a thickness varying according to the upward pressure it should sustain; the lowest portions are rarely more than 3 meters below the bed of the canal, and at this depth in most cases all the work of excavation and masonry can be done dry by means of drainage machines.

The foundations of almost all the works rest solely on a clay more or less sandy, for it would be necessary to go to great depths to meet a more solid soil, and this clay is generally sufficiently compact and homogeneous not to need consolidation by means of stone or otherwise.

The aprons are of beton covered with two courses of brick, with binding courses of cut stone.

The body of high masonry is often of brick, sometimes of rubble with binding courses of cut stone.

The mortar employed is generally formed of one part of fat lime and two of artificial puzzolana made from the débris of broken brick.

In some cases the puzzolana is replaced by the simple mud of the Nile, and they thus obtain a mortar which hardens under water at the end of quite a long time; this mortar is met with in ancient works, but it is no longer employed in public works.

Almost all the fermetures of the regulating works are formed of horizontal stop-planks or vertical needles.

The chief cause of destruction of the Egyptian works lies in the foundation. In the first place, it often happens that unequal settling takes place in the soil, causing cracks which it is necessary to repair carefully when the settling is complete. In the second place, the embankments and the muddy soil being very easily washed away, it may happen that the work is overturned by the current or that the apron may be undermined by the movement of the water; to avoid the first inconveniences they give to the abutments of the works a very considerable length and thickness; to avoid the second they prolong the aprons and consolidate the earth by means of masses of riprap which should often be renewed.

A few years ago it was difficult to find, in the provinces somewhat distant from Cairo, contractors to undertake works of skill, therefore it was necessary to construct them as a tax; this was slow and costly. To-day all the works are done when possible by contract.

The repair of the riprap and the spurs, which are designed to render the bed of the Nile stable and protect the dikes, requires every year great quantities of stone, which amount to as much as from 50,000 to 60,000 cubic meters; in Lower Egypt the stone used for this kind of work is taken from the quarries near Cairo by convicts and transported as far as the Nile by a short railroad a few kilometers long. Here the owners of barges load it and carry it to the place required the foreman, with the men of the *corvée*, unload it, placing it in position. A few years ago contractors quarried the stone, carried it to the Nile, and loaded it on barges; they were paid 2.20 francs per cubic meter.

In Upper Egypt the same contractor who furnished the stone transported it and placed it in position.

VI. EXPENSE OF REPAIRS.

The Egyptian Government carries yearly in its budget, exclusive of the pay of engineers and the *personnel* of the bureau, a sum of about 3,000,000 francs for the repair of the works of skill, of the works of protection against inundation, and for dredging. If we add to this the 12,000,000 francs which is the cost of executing by contract all the work which falls to the *corvée*, it is seen that the cost of repairing the dikes and of the canals of general and communal interest, for the whole of Egypt, amounts annually to 15,000,000 francs. The total cultivable area of Egypt amounts to

2,100,000 hectares; this sum represents 7.14 francs per hectare. But since the *corvée* executes a portion of these works of repair, it is very difficult to determine the exact amount of this expense, and the sum of 7.14 francs, given above, should be considered only as an approximation.

VII. WORKS EXECUTED BY INDIVIDUALS.

On account of the social condition of the country the Egyptian Government has been obliged to take under its own charge, or impose on the whole population, all the works of construction and repair which pertain to works of general and communal interest. There only remains as a charge to individuals the execution and maintenance of their inlets and watering canals for their own property; these works being generally of little importance, syndicates are not appointed in the country, with organizations more or less complicated, to insure irrigation for particular territories.

In some cases small numbers interested unite to construct an inlet on a grand canal; then the Government assumes charge of the work for the farmers; the latter raise in advance the approximate amount of cost, which is divided in proportion to the extent of land cultivated by each individual. As to the repair of the canals and works of special benefit, those interested, who are never very numerous, arrange to have it done among themselves, or, when it concerns the whole or part of a village, the inhabitants form a special *corvée* under the direction of the sheiks or local authorities.

CHAPTER VI.

METHOD OF ELEVATING AND USING IRRIGATION WATER.

ELEVATING-MACHINES—AUTHORITY FOR ESTABLISHING ELEVATING-MACHINES—INLETS—WATERING CANALS.

I. ELEVATING-MACHINES.

When the water flows in the feeder canal, at the level of the cultivated land or above this level, the proprietor in order to water his land has only to open or shut his inlet. This is what is generally done during flood in almost the whole of Egypt; it is also the same during low water in the regions which are situated a short distance from the inlets of the irrigation canals. These canals have a slope less than that of the valley, and it is possible to take water from them by means of regulating works. But these conveniences do not exist; even during flood, for the high lands which border the river, and during low water all along the Nile and along the higher levels of the canals, it is necessary to raise water by means of machines to the level of the soil if it is desired to make summer crops.

Thus there are in Egypt many regions in which the farmer is obliged with much difficulty and much expense to raise, at least during some months of the year, the water of irrigation, and the lands where this obtains are generally considered the most fertile, because they are slightly elevated and consequently free from the inconvenience which results from infiltration and want of drainage.

Of the elevating-machines used in this country, the most part are remarkable for their awkwardness of construction and the simplicity of working them. They are part of the patrimony of primitive tools which have been bequeathed to the present generation by the inventive genius of the first race of farmers, and which have been transmitted through centuries with that kind of tradition and sameness which prevails in the nature and affairs of the Orient. For these awkward machines, whose arrangements are based on the use of man and animal power have been partly substituted, during the present century, the steam engine and the pump, usually the centrifugal pump.

The wind is not employed in Egypt for working irrigation machines.

*Nattal.**—When the height to which the water is to be raised is from 50 or 60 centimeters, and does not exceed one meter, they cut into the banks of the canal so as to make a small platform as high as the level of the water, or a little above this level, and they carry the supply ditch as far as the side of this small platform, being careful to terminate it by an earthen dam covered with a straw mat to strengthen it. Two men place themselves on this platform opposite each other, on each side of the ditch, so that its extremity comes exactly to the middle of the space which separates them, and which is about 1.50 meters; they are nearly or half seated upon two small mounds of dry mud or simply leaning against the vertical sides which have been dug in the bank to form the platform. The machine worked by these two men is composed simply of a kind of basket, with stiff sides of woven palm leaves, 40 centimeters in diameter and 25 centimeters

* See Plate XVIII.

high; its bottom is sometimes covered with leather, and it is furnished with four cords. The two men, holding one of the cords in each hand, taking a balancing movement, throw the basket into the canal; then they raise it up, throwing it back at the height of the body, bringing it to the end of the ditch, and each of them make with their arms a movement like that of the laborer who empties his wheelbarrow by the side; the contents of the basket is thus emptied into the ditch.

Two men can raise by this method from 4 to 5 cubic meters per hour.

This simple plant is called the *nattal*; it is cheap and easy to establish anywhere.

The small amount of earthwork necessary is made very cheaply in consequence of the plasticity of the Egyptian soil, which maintains itself almost vertical, and which, when it is used wet, takes and preserves, after having been dried, any form which may be given it.

Chadouf.*—When the height exceeds 1 meter, the effort which the men are obliged to make to raise the basket of the *nattal* becomes too fatiguing. They then place the basket on a lever, which allows the amplitude of its movement to be increased, and they thus obtain a new machine, which is called *chadouf*, and which suffices to elevate water as high as 3 meters.

The *chadouf* is composed essentially of two vertical supports of about 1.20 meters in height, and 1 meter apart, supporting at their upper extremity a wooden beam from which is suspended a large lever about 3 meters long; palm cords and a small wooden axis afford the means of suspending the lever to its beam. The two vertical supports are generally formed either of forked branches or fascines of rushes placed in the ground and bound together by means of dry mud. At one of the extremities of the lever hangs a basket similar to that of the *nattal*, fastened by means of movable arms of about 2½ meters long and palm cords. The other extremity is counterpoised by dry mud sufficient to draw up a basket filled with water.

This machine is placed in position so that the lever works parallel to the ditch to be supplied and perpendicular to the canal. A small trench conducts the water of the canal to the *chadouf*, and the man charged with maneuvering the machine stands on a small platform established about 1 meter below the ditch to be supplied and formed either of a small mound of earth or some brush; he stands erect, his back supported against the sides of the trench by which the water of the canal comes to the *chadouf*. In this position he bears his weight on the suspension arm of the basket until it reaches the water and is filled; the counterpoise then acts to raise the basket to the level of the ditch into which the man empties it by a movement of the handle.

Sometimes, in certain localities far from the Nile and canals, they use the *chadouf* to raise the irrigation water from wells dug to the depth of 4 or 5 meters below the soil, but these heights are very exceptional.

Generally when they wish to raise water more than 3 meters they place *chadoufs* over each other, each machine taking water from the basin into which the lower *chadouf* has already raised it. Frequently on the banks of the Nile in Upper Egypt the traveler encounters numerous *chadoufs* working thus, in ranks of three or four front, and with three or even four different levels. The sight is very picturesque; these levers rising and descending slowly in cadence under the regular impulsion given them by negroes or fellahs, bronzed by the sun, almost naked, dripping with water, and keeping time to a nasal chant which one of the workmen raises from time to time, and which mingles with the rippling of the falling water.

Like the *nattal*, the *chadouf* is a simple plant, which can be established wherever desired and removed with the greatest facility and, it might be said, without expense. Two bundles of corn-stalks or reeds, two sticks, a little cord, a basket, and a piece of leather are the materials which compose it; every fellah possesses these, and the mud of the Nile is sufficient to place them in working order.

The movement of the *chadouf* is slow; a man can hardly raise, in the usual conditions, more than ten baskets per minute; at 10 liters per basket, this makes 100 liters per minute and 6 cubic meters per hour. One man works at the *chadouf* about two hours at a time. It is generally admitted that one machine with two men is necessary to water one-half hectare.

From numerous observations made on this subject by the engineers of the French expedition in Egypt, it is concluded that the work produced by the fellah with the *chadouf* is 330 kilogram-meters on the average per minute, while the dynamic action of a man of mean strength, raising

* See Plate XIX.

weights with a cord and pulley and lowering the cord without weight, is ordinarily considered as only 216 kilogrammeters for the same time. The *chadoufs*, therefore, utilize in an advantageous manner the muscular force of the workman, since he acts by his own weight to raise the counterpoise and to lower the empty basket, and the water then is naturally raised by the effect of the counterpoise and without effort on the part of the man.

Sakie.^{*}—For heights above 3 meters the *chadouf* is an onerous machine, consequently they employ most frequently in this case a kind of *noria* which is called *sakie*.

The *sakie* is very common in Egypt. It is arranged in the following manner: A wooden wheel about 1.50 meters in diameter is furnished with cogs 20 centimeters long; the axis of this wheel is vertical; it rests at its lower part below the level of the soil on a large step formed of pieces of wood laid together, and is bound by cords in a fixed manner to a horizontal lever 3 meters long, which, moved by an ox or other animal, carries with its revolution the horizontal wheel. The upper extremity of the vertical axis passes into a bearing roughly made of iron or wood and which is fixed to the horizontal beam 6 or 7 meters long, whose ends rest on two supports of dry mud, sun-dried bricks, or masonry built on the ground upon which the animal motor passes. Frequently the shaft of the wheel is formed by a rough branch which separates above in the form of a large crotch whose two arms facilitate the connection with the horizontal lever of the machine. Sometimes for small *sakies* the upper beam is discarded; the *sakie* is then kept vertical by means of wooden beams placed horizontally at the level of the soil.

The horizontal wheel engages a vertical wooden cog-wheel about 1 meter in diameter, carrying cogs similar to those of the horizontal wheel, with its axis passing below the level of the soil under the track, and carrying on its other extremity a wheel from 1.50 to 2 meters in diameter, which supports the chain of the *noria*. This chain is simply formed of a rope ladder carrying earthenware pots spaced about 50 centimeters apart, which are raised full of water to the top of the wheel and empty into a trough placed laterally.

To resume, the *sakie* is composed of an arrangement giving movement to a crown wheel which engages the vertical wheel carrying the chain of the *noria*. Each machine is roughly made from the wood of the *acacia*, which is found in the country and which is hardly ever used squared. Consequently the vicinity of a *sakie* is announced from afar by the continual groaning and the incessant plaint of the machine, raising itself in the stillness of the plain or disturbing the silence of the night, a witness of the effort at whose cost man brings fertility to the parched earth. Frequently the *sakies* are arranged along the banks of the Nile or the great canals, as might be said, temporarily; the earthen bank serves as their foundation. The pit into which the *noria* descends has vertical sides dug in the mud; it is partially covered by a few branches covered with earth, over which the animal which turns the machine passes. The supports of the upper beam are in this case simply masses of earth.

But some *sakies* are also established permanently either at the wells in the midst of the fields or on the banks of the canals; they are then surrounded by trees, which protect the men and animals from the sun. They are established on masses of masonry. The wells of the *noria* are also of masonry; sometimes they also place two, three, or four *sakies* at the angles of the same well. These wells, as all those which are seen in Egypt, are constructed on wooden curbing, below which the earth is removed, causing them to descend as the masonry advances, they are generally of brick, and are partially covered by small arches designed to support the axis of the *norias* and the discharge troughs.

The large *sakies* are worked by two oxen, but often a single one is employed or a buffalo; sometimes an ass, sometimes a horse, and even a camel. The oxen or buffalo which work the *sakies* are relieved every three hours.

It is estimated that the *sakie* does the work of 4 *chadoufs*, and that it suffices for the irrigation of 2 to 2½ hectares. Under the general condition under which agriculture is carried on they require the employment of three buffaloes and two men.

From a series of experiments made by the French expedition in Egypt it was shown that the contents of the jars of a *sakie* being 1.60 liters and the weight of a jar nearly 1 kilogram, the

^{*} See Plate XX.

discharge of such a sakie varies from 4,200 to 4,800 liters per hour, according to the height that the water is raised, and this height often reaches 10 and 11 meters.

The delivery of these machines is very variable, because the capacity of the jars not being generally in proportion to the height raised, it happens for small elevations of level that the animal power is not obliged to develop all its capacity.

Moreover, often for heights of 10 and 11 meters the delivery is still small, on account of the rudeness of construction of the cog-wheels and the very imperfect adjustment of the different parts of the machine. Thus, in the experiments cited above, it was found that a horse moving the sakie and raising water to a height of 10 meters only effected 718 kilogrammeters a minute. Now, the power of a horse attached to a lever and turning at the average speed is estimated in Europe at 2,430 kilogrammeters per minute; allowing the difference in strength between the Egyptian horse and the European horse, it is found then that the work of the sakie is not economical. While the ox can produce normally the work of 2,160 kilogrammeters per minute, in raising water with a sakie to the height of 10 meters it only utilizes the work of about 700 kilogrammeters.

Therefore, although the sakie is a cheap machine in construction and installation, it is of small economy in the work accomplished. Nevertheless this machine is the one most used in Egypt for raising water. There are nearly 12,000 in the part of the Delta comprised between the branches of the Damietta and Rosetta, which includes a total cultivable area of 500,000 hectares, and taking this as a basis it is seen that in the whole of Lower Egypt, which has an area of 1,150,000 hectares, there are 28,000 sakes.

In some places in Lower Egypt and at Fayoum the sakie has undergone certain improvements which make them more economical machines. The extremity of the axes and the pivots have been bound with iron, which diminishes the friction, and the chain of jars have been replaced by a noria, whose buckets are constructed of zinc or of wood which are 60 centimeters long, 30 centimeters wide, and 30 centimeters deep. These sakes with a single animal motor suffice almost for the watering of half a hectare in twelve hours, while the ordinary sakie hardly waters more than a quarter of a hectare in the same time.*

Tabout.†—In the north of Lower Egypt whenever the water is to be raised at least 3 meters they do not use the noria, but a wheel around whose circumference are arranged dippers in which the water is raised, from which it is delivered into a lateral trough, and from thence to the irrigation ditch. This wheel is moved in the same manner as the wheel which carries the noria. The animal motor is generally a buffalo or an ox.

The water is brought by a ditch to the pits dug under the elevating wheel. The wheel is arranged so that the bottom of the trough into which the water is emptied will be at about one-third the height of the wheel from the top in reference to the level of the soil. Contrary to other irrigation machines employed in Egypt, this wheel is made with care and well adjusted. The carpenter work is composed of four arms made of four uprights fixed around a hub. The circumference is formed like that of an ordinary wheel with buckets—the buckets being replaced by simple paddle-boards, whose troughs are completely closed by a circular border, presenting only one line of openings arranged along the base of each paddle, one of the lateral crowns only being pierced by an opening at the base of each bucket near the interior edge of the crown.

The water enters the buckets by an exterior opening, is raised by the movement of the wheel, and emptied by a lateral opening into the wooden tank when the bucket arrives near the top of its path.

HYDRAULIC WHEELS WITH PADDLES.‡

All the preceding machines are moved by man and animals.

In Fayoum, where the canals have a very considerable slope, more than in the rest of Egypt, they use water power to move the paddle-wheels, which carry on their circumference earthen jars, by means of which the water is raised to the level of the land. These wheels are similar to those in the vicinity of Palma, and which are described in the work of M. M. Aymard on irrigation in the south of Spain.

* See Plate XXI, Figs. 1, 2, 3, 4, 5.

† See Plate XV, Figs. 1, 2, 3.

‡ See Plate XXI, Figs. 6 and 7.

Some of these wheels are placed in the bed itself of the Bahr Youssef, at a point where the slope of the water-course is almost 50 centimeters per kilometer; they are moved by the force of the current. But most frequently they are established at the head of the canals or on their course. The canal is then inclosed between two masonry walls which hold the wheel and support its axis. They use at these points as a motive force falls of water of from 30 to 60 centimeters in height. Many wheels are established in this manner in batteries side by side or one behind the other.

The dimensions of these wheels are very variable; generally they are 4.50 meters in diameter, are furnished with twelve paddles 90 centimeters long by 60 centimeters wide, and carry a chain of twenty-four earthen jars of 7 liters capacity. These make nearly, under these conditions, four revolutions per minute, and raise therefore 40 cubic meters of water per hour to an average height of about 3 meters. They can furnish, therefore, in eighteen hours a good watering to one hectare. It is estimated that one of these wheels is sufficient to irrigate for the summer crops an area of 13 cultivated hectares.

Some wheels carry two chains of earthenware buckets on each side of the paddles. There are besides these wheels of larger diameter which carry as many as ninety-six jars in two chains.

STEAM-PUMPS.

For some years the employment of steam as a motive power for works of irrigation has been much developed in Egypt, thanks to the increasing cheapness of engines and boilers. With a steam-engine the elevating machine is generally a centrifugal pump, more rarely an ordinary pump, and exceptionally a drum or hydraulic wheels of some kind. The centrifugal pump is so easy to move and put up that it is most favored.

The plant most used in Egypt consists of a locomotive engine covered by a small shed or an earthen hut covered with an earthen roof; a few paces distant on the bank of the canal the centrifugal pump is connected to the motor by a pulley. There are also, nearly everywhere, permanent machines also working centrifugal pumps; the ordinary pumps are hardly met with in the most important and oldest establishments. All these machines and their installation differ nothing from those which are found all over the world; it is then useless to describe them.

According to the statistics collected by the ministry of public works there were in 1882, in the whole of Lower Egypt, 2,500 machines representing a total of 25,000 horse-power, among which three hundred and sixty permanent machines have a total of 6,000 horse-power.

In Upper Egypt there are in all one hundred and fifty machines representing 4,700 horse-power, among which there are fifty-six permanent machines with a total of 3,600 horse-power.

A little less than one-fifth of these machines are established on the banks of the Nile and Damietta and Rosetta branches; the others are on the banks of the canals.

The installation of permanent machines on the banks of the Nile presents great difficulties on account of the incessant change of the lesser and even the greater bed of the river. Frequently considerable plants have been abandoned on account of the banks of sand accumulated in front of the suction of the pumps, it was necessary each year to dig through these deposits along the feeding canal.

To insure in spite of the vagaries of the river the watering of the sugar-cane plantations in the region of the south of Upper Egypt, where summer cultivation can only be carried on by raising water from the Nile by machines, M. Gay-Lussac, administrator of the Daira Sanieh, introduced the scheme of placing on a barge a rotary pump of the Griendl system, moved by an oscillating engine. The delivery tube is raised vertically, supported by a kind of shears, to the variable height of the banks of the river above the level of the water. This tube is prolonged then for a greater or less length in proportion to the distance of the barge from the bank. They can also, with a long swing, avoid very frequently giving great lengths to these tubes; it suffices, in fact, to move the boat and place it each year at a place where the river flows near the bank; a few works of connection with the watering canals complete, without expense, this essentially movable installation, which up to the present has given good results.

Steam-engines used for irrigation are fired generally with coal, but whenever possible the farmer uses as fuel, the stalks or the straw provided by the crops, or the stalks of the cotton plant.

It is calculated that in Egypt, in ground of mean altitude, it requires 110 kilograms of coal, or 290 kilograms of cotton stalks, to water one hectare. This represents nearly the sum of 5 francs. But this amount is very often less than the actual cost, because the engines are badly tended and use more coal than is necessary. In 1883 the administration of the domains of the Egyptian state calculated that it had, during the year, irrigated by steam a surface which, multiplied by the number of waterings, represented an area of 102,817 hectares, irrigated once only. For such a number of waterings the average expense for coal, oil, etc., was 3 francs 56 centimes for one watering per hectare, or for the elevation of 700 or 800 cubic meters, which represents a quantity of water necessary for the watering of one hectare.

Expense to the farmer for raising water.—The necessity of raising water is one of the heaviest charges which is imposed on every farmer in Egypt, and every project for the amelioration of irrigation in this country should have as its principal end the abolition, as much as possible, of the elevating-machines. The necessity of working the *sakies*, in fact, forces the peasant to feed a number of animals, which are costly to maintain on a soil where natural pasturage does not exist, and which badly fed are of no use, and besides are of almost no other utility than for the work of watering, and which, weakened by fatigue, are without strength to resist epizooty, so frequent in this country. On the other hand, if the fellah, for want of animals, desires to use steam for raising water, he needs a large amount of funds to buy and install the pump and engine, and if he is not able to bear this expense he finds himself given over without mercy to his richer neighbors, who use him and oppress him at the time of the drought, and extort from him a part of his crops, allowing him to save the other part by a scanty watering. Some owners of machines go so far as to force the small farmer to pay more than 50 francs to one hectare; they always demand for their pay one-third of the crop. In many regions the price paid for watering by steam is 25 francs per hectare by the unfortunate small proprietor; this is the usual price, although it is at least five times greater than the actual cost of raising water.

II. AUTHORITY FOR ESTABLISHING ELEVATING-MACHINES.

In Egypt every one places, without authority, at his watering ditch or his field on the borders of the Nile or canals the *chadoufs* and *sakies* which he thinks necessary for his crops, and moves them as may be required. It is not, however, the same with the more important elevating-machines. The establishment of these machines is regulated by the decree of the 8th of March, 1881, whose principal articles are shown below:

DECREE AND REGULATIONS CONCERNING ELEVATING-MACHINES.

ARTICLE 1. The establishment of machines for elevating water for irrigation is forbidden, whether these machines are fixed or movable, whether they are moved by steam or by water power, or by the wind, without previously obtaining the authority of the ministry of public works.

This authority does not give to the beneficiary proprietor the right, to any extent whatever, over the land of the state, either public or private, or land crossed by syphons, culverts, or aqueducts for obtaining water or to supply pumps.

The Government is to remain exempt in all controversies between third parties and the beneficiaries, and the latter are to be responsible for all acts, damaging or otherwise, by the installation, or in any manner.

ARTICLE 2. The establishment of fixed machines will only be allowed on the bank of the Nile. However, the ministry of public works will allow their exceptional establishment on certain canals. The ministry remains sole judge of the necessity of this authority, and it reserves entire liberty to impose, according to the case, the charges and conditions to which it will be subjected.

ARTICLE 3. Every elevating-machine, fixed or movable, is subject to the general obligation of leaving entirely free all communication along the dikes and canals, of respecting all works, and not interfering in any way with the repair of these dikes and canals, and the protection of the country against inundation.

ARTICLE 4. The neglect of any condition or obligation imposed by the authority for establishing an elevating-machine forfeits entirely this authority, without prejudice or recourse, while the Government reserves to itself the right of repairing the damages and reimbursing the state for the expense.

ARTICLE 5. Installations authorized at a particular place can only be moved by a new authority, without payment for the new right.

ARTICLE 6. The Government reserves the right, on account of public utility (execution of public works, danger to dikes, works of skill, etc.), to remove every authorized installation.

ARTICLE 7. The authority given to install a fixed or movable elevating-machine gives the right only to the grantees making an installation to take water from the canal or from the Nile. It does not bring any obligation to the Gov-

ernment of insuring the constant supply of the machine. For conducting the water furnished by the machine the grantees must have an understanding with the society of owners whose lands they will have to cross, without the intervention of the Government.

To pass the water across the unoccupied lands or over the lands of the Government the grantees will be furnished with a special authority.

Ditches for bringing water are forbidden along the dikes of the canals and the Nile, as well as along the banks and alopes of these dikes.

ARTICLE 8. The ditches or conduits for bringing the water of the machine to the land will be established so as to hinder in no way public travel, and the passage of water of drainage and irrigation shall be subject to the reserved rights of proprietors, to whom the grantees alone remain responsible. The Government requires for passage under the dikes and roads above and below the canals all the works which it may judge proper.

ARTICLE 9. For the general benefit in the case of exceptional low water, or when the discharge of the canal becomes notably less than the needs of the crops which it serves, the service of the public works may, either for the whole canal or for a single level of the canal, determine the reduced discharge, or, if it is necessary, temporarily stop the machines, according to the relative importance of the works and the land which they water, without, in this case, the Government taking any responsibility for damage caused to the crops.

ARTICLE 10. By authority of article 7, the ministry of public works may, in exceptional cases, authorize the use of a Nili canal (canal of inundation) for conducting the water from the elevating-machines to the land to be watered; that is, under the following restrictions:

(1) This permission will only be good in seasons of low water, and will terminate then when the water of the Nile can freely enter the canal.

(2) It will only be accorded when the proprietors of the land which have the use of this Nili canal have given their general assent to this permission.

(3) If dikes for holding up the water at the mouth of the canal or on the course of the Nili canal are built they will be of earth, and must be raised at the expense of the proprietor of the machine, if necessary under the supervision of the authorities, but at the cost, risk, and peril of the proprietor, before the water of the Nile can freely enter into the canal.

(4) Finally, the proprietor of the machine is alone responsible to the farmers for every damage occasioned by the rupture of dikes, infiltration, and delay in raising the dikes at the time of supply. * * *

ARTICLE 13. The proprietors of the elevating machines are responsible for accidents or damages which may be occasioned by these machines.

The Government reserves, however, the right to exercise, in the public interest, the supervision of the working of the machines, without freeing the proprietors from the responsibility incumbent upon them. The cost for obtaining authority for establishing machines are,* first, the fixed sum of 26 francs per machine for expense of examination; second, the charge of 13 francs per horse-power, the sum never being less than 130 francs.

III. INLETS.

The decree given above is, so to say, the only law for regulating the distribution of the waters of irrigation in Egypt.

Thus, on the one hand, the Government delivers the water in the canals at the level and the discharge which it judges proper, and it maneuvers at its pleasure the regulating works; on the other hand, the cultivators place on these canals, as many as they desire and at the places which suits them, their sakies and chadoufs.

When it is a question of raising water from canals with steam-pumps, the Government always determines whether it should interfere to regulate the position, power, and discharge of these machines, lest these powerful machines may dry up the canal and bring trouble to the general distribution, and it interferes also when the proprietor wishes to establish a fixed inlet.

The private inlets are generally of the greatest simplicity. The most rudimentary and most numerous consist of a drain cut in the banks of the canal, sometimes 5 or 6 meters in depth below the crest of the dike, a drain whose sides are maintained vertically on account of the stiffness of the mud. These trenches are barely covered by light branches, which serve for bridging them, and they create along the dikes great obstacles to travel, because in Egypt the banks of the canals are almost the only existing public roads. The administration has not yet imposed on the cultivator the obligation of substituting for these too primitive inlets the employment of iron or clay pipes. This kind of inlet serves everywhere for the sakies and chadoufs and centrifugal pumps moved by locomotive engines.

* These charges are fixed in Egyptian piasters and pounds. The piaster is worth nearly 26 centimes, and the pound 26 francs. These are the values adopted in this work for changing Egyptian money to French.

For the fixed machines and for the important inlets drawing from the water level, masonry conduits are built, with fermetures made of turning-gates or needles. These works are constructed by authority under the supervision and control of Government agents.

Otherwise there is nothing special to mention on the subject of inlets, the regulation of their discharge being a thing unknown in Egypt.

IV. WATERING CANALS.

As soon as the water has arrived in the trench the cultivator conducts it to the entrance of his fields, which he has carefully prepared so as to be able to spread the water over their whole surface.

Generally the soil is so level that there is no need of great labor to level it and render it fit for irrigation. When it is necessary they employ an instrument like a wheelbarrow, without wheels and without legs, furnished behind with two handles. An ox or a buffalo is fastened in front, a man holds the handles behind and bears on the box so as to scrape off the earth with the front border, which is much inclined and covered with a strip of iron. The box is filled with the products which are scraped up, and by a single movement of the lever fastened to the handles the man empties it into the low places. This is used in almost all irrigated countries.

When the ground is thus planed down the watering is accomplished by different methods.

Generally the soil is divided by small ditches into squares of 30 or 40 meters in area; then they are submerged successively for a few centimeters in depth. This method is employed for the watering which is given before the crops are up or even sown.

Later, when the crops are up out of the ground, the watering is done according to the nature of the crop, either in the furrows serving as ditches or by submerging the squares, as above mentioned.

For rice fields the water circulates continually in a series of successive basins separated by small earthen dikes.

In other respects the method used in Egypt for the employment of water for irrigation presents no special peculiarities worthy of mention and does not differ from those which are employed in all flat countries.

CHAPTER VII.

CROPS CULTIVATED IN EGYPT.

CROPS—MANAGEMENT OF THE LAND—FERTILIZERS—METHOD OF FARMING THE LAND.

In order to appreciate the rôle that irrigation plays in the country, and what advantages it secures for it, it is indispensable to know the kind of crops which are cultivated and the method of management of the land. This chapter has for its object a few summary indications concerning the different kinds of plants which are cultivated in Egypt, and especially to point out the peculiarities which pertain to the time of sowing and watering, and of the harvest, and to the profits from the land, and to the distribution of the crops.

There are no agricultural statistics in Egypt which allow an estimate of the fertility of each province, and we know how difficult it is to obtain, in every country, from farmers exact data on this subject. In what follows, the deductions which pertain to the returns from the lands have been furnished by the annual report of the administration of the domains of the state and Diara Sanieh, whose properties are scattered throughout the different regions of Egypt; * they may be considered as representing an average for the whole country, although they have been notably lower than the data generally accepted.

I. CROPS.

Wheat.—Wheat is a winter crop; it is sown after the flood or about the end of October, or in the month of November, according to the locality, and the harvest is made toward the end of March or in the month of April.

In the inundation basins they sow on the ground while it is yet muddy, then they roll the soil with the trunk of a palm tree, merely to cover the grain. Sometimes, when the sowing is done in a soil of more consistency, it is worked after the sowing. They do not water the lands before the harvest.

In the irrigated lands the first working is done before the sowing and the second one afterward. The land has been watered and washed with the flood waters before the first working; they give afterward but two waterings, the first sixty days and the second ninety days after the sowing.

In high lands which only receive the water of the flood they sometimes give four, five, and even six waterings. The wheat cultivated in Egypt is a kind of hard wheat containing much starch.

The quantity of seed employed on an average is 1.70 hectoliters per hectare in the basins, and from 2.10 hectoliters to 2.30 hectoliters in Lower Egypt.

The produce of the harvest may go as high, in the better lands, as 24 to 25 hectoliters per hectare; but the average is much less than this amount, and, according to the reports of the administration of the domains of the state, which refer to 145,000 hectares of crop, scattered throughout

* The unit of arable surface adopted in Egypt is the Feddan, which is about 4,200 square meters.

the whole of Lower Egypt, the amount produced per hectare of wheat in the last five years has only been on the average 14 hectoliters and 40 liters.

The mean price of a hectare of wheat being 12.20 francs, the gross product of a hectare is 176 francs, to which should be added the price of the wheat straw, which is carefully gathered for feeding the cattle, and even for fuel for the steam irrigation machines. The quantity of straw is nearly 90 kilograms per hectoliter of wheat, which represents about 1,300 kilograms per hectare, at 1.50 francs per hundred kilograms, or 20 francs per hectare. The total gross product of a hectare of wheat is then, on an average, 196 francs.

The thrashing of the wheat and the chopping of the straw is done with a very peculiar machine called *noreg*, in the following manner. The wheat is spread in a circular zone upon a platform of hard earth; a pair of oxen or buffaloes pass over the circular space thus laid out, dragging a kind of wooden chariot composed of a seat upon which the driver sits, mounted on two wooden wheels furnished at intervals with projecting disks of sheet-iron; the passage of these disks, upon which the *noreg* rolls, and the treading of the animals separates the grain from the husks, and at the same time breaks the straw.

Barley.—Barley, like wheat, is a winter crop which is very extensive in Egypt.

In the most southern part of Upper Egypt, to the south of the region of the basins, they sow it at the end of November, after having given the land a first watering and divided it into squares by small dikes, and submerging it by means of chadoufs and sakies. They are obliged to water it artificially the entire time that the crop remains in the ground, or until the end of March.

In the basins barley is cultivated like wheat in the inundated lands, after the land has become somewhat dry, with one working or without any working, according to circumstances; but when no working is made they are obliged to increase the quantity of seed.

In the Delta the cultivation of barley goes on like that of wheat, and at the same time as the latter, after the flood and with two or three artificial waterings.

The quantity of seed employed varies from 1.10 to 2.20 hectoliters per hectare, according to the nature of the ground.

The product of the harvest is very variable; it may go as high, in certain places, as 30 hectoliters per hectare; but most frequently it does not exceed the half of this; for the large farms, comprising lands of every kind, they can not count on an average of more than 10 hectoliters per hectare.

The average price of a hectoliter of barley, during late years, has been 7.50 francs.

A hectoliter of barley corresponds to nearly 75 kilograms of straw, which is worth on an average 1.30 francs a hundred kilograms.

The gross product of a hectare sown in barley is then, on an average, 88 francs.

The barley is mostly used for feeding cattle.

Indian corn and dourah.—Corn and dourah, a kind of sorghum, are two plants which play a special rôle in the agriculture of Egypt, in the sense that they are those which furnish for the peasant the greater part of his food. Also, they are cultivated throughout the whole expanse of country, and as they are crops which mature quickly, they are used in this country for intermediate crops, between the summer and winter crops.

Corn only remains, on an average, three months in the ground.

In the region of the basins they cultivate corn either in the high grounds, on the banks of the Nile, or in certain low parts of the basins, where they are able by digging slightly to meet the infiltration water, which they raise by means of chadoufs to the surface of the soil. In this latter case the sowing is done in the month of May in order that the harvest may be gathered about the end of August, when the basins are refilled. In the first case the sowing is done most frequently at the end of August, at the time when the water of the river is already sufficiently high to facilitate watering. The flood always reaches a level sufficiently high so that the roots of the crops are entirely submerged in the water for some days; this diminishes the expense of irrigation.

For this crop they divide the land, by small dikes, into squares of 25 or 30 meters in area, and they sow the grain in ditches 10 centimeters in depth; they then cover the grain and begin watering. They give water at first for a few days in order to moisten the land and to hasten germina-

tion, then they water regularly every eight or ten days. These crops are troublesome, because, being made at the time of greatest heat, they require much water.

In Lower Egypt, and in all the irrigated lands, corn is always cultivated, either as a spring crop, sown in May, or as an autumn crop, sown in August.

They also arrange so that the sowing generally takes place at the time when the watering may be made by chadoufs or without watering machines, and as much as possible without sakies and without steam pumps, because these are crops which should be worked with economy.

In the regions of irrigation, as the method of agriculture here is more exacting than in the basins of inundation, it is necessary to hasten the development of corn with fertilizers, in order that the plants may remain as little as possible in the earth and give place to other crops. They employ for this purpose the ashes and earth taken from the ruins of old cities and they spread about 7 or 8 tons per hectare. They then work the land and they sow in hills or in furrows, then divide the fields into squares, as has been mentioned above, and give one watering every fifteen days for from two and one-half months to three months; or about six waterings.

The quantity of seed employed is a little less than one hectoliter per hectare. The product of the harvest is very variable; they may obtain as high as 25 hectoliters per hectare in the good lands, and as a mean for Egypt about half, or 12.50 hectoliters per hectare.

The average price is 8 francs per hectoliter.

The corn stalks, used principally to burn under the boilers of the steam-engines, sell at 0.45 francs a hundred kilograms, and represent for the product of 12.50 hectoliters per hectare a weight of about 900 kilograms.

The gross mean product of a hectare is then, including stalks, 104 francs.

All that has been said of corn applies almost exactly to dourah; it is not then necessary to mention especially this plant, which is entirely similar to corn in its method of culture and as to its product.

Rice.—The culture of rice is carried on only in the north of Lower Egypt. In this region the lands are low they can therefore be easily watered. To raise the water, in case it is necessary, they employ *tabouts*, and according to the height to be raised they place from 1 to 3 of these wheels to 4 hectares.

The rice is cultivated in summer; it is sown at the commencement of April; the quantity of seed employed is 1.70 hectoliters per hectare.

The ground before being sown is covered with water for some days; they then work it in two directions, at right angles. They submerge the soil, roll it, wet it, divide it into basins by small dikes, and finally throw the seed into the mire which is formed by these operations. Two days after the sowing they recover the land with 5 centimeters of water for two or three days, they then allow the water to drain off; they renew it, and repeat this until the harvest. Frequently they give water in too great quantities. They weed the rice fields from time to time.

The harvest takes place about the middle of November, and since at this time of the year there is much water over the low lands it is always made under 25 to 30 centimeters of water.

As soon as the rice is harvested it is thrashed and hulled in special mills. It is estimated that 5 hectolitres of hull rice give 4 hectoliters of clean.

The mean product is 1,800 kilograms of hull rice per hectare; it is, however, very variable and may reach double this quantity. The average value of rice in Egypt is 18.25 francs a hundred kilograms. A hectare of rice produces besides 1,000 kilograms of straw at 50 centimes a hundred kilograms.

The gross product of a hectare of rice is then, on an average, about 333 francs.

Sugar-cane.—Sugar-cane is the most important summer crop of Upper Egypt. It only grows in irrigated lands, and only prospers in a soil of good quality. Thus in certain parts of the Ibrahieh region and of Fayoum, where it grew formerly, they have been forced to give up its cultivation, because the soil not having sufficient drainage has been affected by the salts, and the product has become too small in consequence of this circumstance. At present there is no cultivation of sugar-cane except in the northern province of Beni-Souef, and it is one of the departments of the Government, called Daira Sanieh, which produces it in great quantities, and which has the most important and numerous plants for extracting the sugar.

This administration organizes its crops as follows:

The land is broken up as much as possible by a steam-plow, after which it receives three cross-workings, sometimes only two. These operations are carried on from the month of March to the month of November of the following year.

In November they make furrows for planting with a hoe or with a plow; these furrows are about 15 centimeters deep. The planting is generally in lines, by laying in the furrows cuttings from 40 to 50 centimeters in length, in two rows in quincunx order. These cuttings are then covered up with a hoe. They plant in this way the cane at the rate of 500 kilograms of stalks per hectare. This planting is performed in March or April.

After placing the cuttings in the furrows they immediately give one watering; then the waterings succeed each other every ten days until the end of August; from this epoch till the end of October they only water every fifteen or twenty days, according to the appearance of the crop. After October they do not water the crop before the harvest, which takes place from the end of October to the 15th of March.

The cane after one cutting is still able to produce good stalks the following year; thus they avoid the expense of working and planting. The only treatment to be given to the land in this case consists in throwing the earth up against the plant with a plow when the shoot is about the height of 15 or 20 centimeters. As soon as the cane matures it is cut and carried on the backs of camels to the agricultural railroad, which crosses the properties of the Diara, then placed in cars and transported to the sugar-mills, where it undergoes the usual operations. The produce of a hectare is very variable, according to the quality of the ground and the abundance of waterings. Some lauds give as high as 62 tons of cane per hectare, but the average is only 23 tons.

The average returns of sugar from the cane of the Daira Sanieh is about—

Sugar:	
First throw.....	5.8 per cent. of the weight of the cane.
Second throw.....	1.73 per cent. of the weight of the cane.
Third throw.....	0.52 per cent. of the weight of the cane.
Total.....	8.05 per cent. of the weight of the cane.
Molasses.....	1.98 per cent. of the weight of the cane.
Total.....	10.03

The selling price has always been falling during the last years; the average has been :

For 100 kilograms of sugar:	Francs.
First throw	50.29
Second throw	38.47
Third throw.....	31.81
For 1 kilogram of alcohol.....	0.75
For 100 kilograms of molasses	5.00

The average product of a hectare planted in sugar-cane then is, after manufacturing and delivering the sugar at the place of sale, that is at Alexandria, about 1,020 francs.

Clover, Greek fennel, vetch, field peas.—Clover is a fodder of very common use throughout the whole of Egypt. It is cultivated during the winter and also during the autumn.

In the latter case, they sow it in the corn during the month of November, about one month before the maturity of this latter crop. They thus utilize the watering of the corn, and as soon as this crop is gathered it suffices to give one watering to the former before cutting, which is done fifty or sixty days after sowing. They use about 90 liters of seed per hectare. As to the winter clover, in the basins they sow it without working, in the inundation lands, in the month of November, at the rate of 100 and 110 liters of grain per hectare. They roll the soil with a trunk of a palm tree, and make the first cutting at the end of forty or forty-five days; the second thirty days after that. In the portions where they wish to harvest the seed they only make one cutting.

In Lower Egypt the winter clover is sown about the same time, or in November, after one working and one rolling, and one division of the land into squares by small dikes. They use 110 liters of seed per hectare. They generally make three cuttings; the first sixty days after sowing, the second thirty days after that. The harvest remains then in the ground about four and one-

half months. Sometimes they only make two cuttings. Finally, very frequently the different cuttings are eaten, while still growing in the fields, by the cattle.

It is seldom in Egypt that they give green forage to animals more than two to two and one-half months in winter, and it is estimated that ten oxen consume nearly a hectare of green clover. The cattle contribute at the same time to enrich the land on which they pasture; but the greater part of the manure is collected to be dried and made into fuel.

A crop of clover requires on an average eight waterings, or almost one every fifteen days.

In the region of the rice fields clover is sown immediately after the harvesting of the rice, or about the end of November, without any other preparation of the soil than covering it with a few centimeters of water for two or three days.

Vetches and peas are cultivated everywhere in Upper Egypt. They reap this fodder at the end of sixty days, to be feed green.

The Greek fennel, or helve, is a foreign plant, whose grain is edible. It is a species kindred to the melilots. It is cultivated like clover. They pull it sixty or seventy days after sowing.

Beans.—The bean is one of the plants which prosper best in Egypt; it is also very extensive here. It is a winter crop.

In the basins they sow it on the inundated lands at the beginning of November without working. The harvest is made in February, or at the end of three months and a half. The quantity of seed used is from 3 to 4 hectoliters per hectare.

In Lower Egypt beans are also sown in November, after the flood, at the rate of 3 hectoliters to the hectare. They give one working to the land before sowing. The seed is most generally placed in furrows; they then level the ground and divide it into squares by small dikes. Two or three waterings in all suffice for a crop of beans.

The bean is cultivated as food for man and animals.

The product of a hectare of beans is very variable; it may go as high as 20 or even 25 hectoliters of beans in good lands, but on an average it will not amount to more than 11 hectoliters.

The average price is 11.50 francs a hectoliter. A hectare of beans affords besides about 80 kilograms of straw per hectare, at 75 centimes a hundred kilograms.

The gross product of a hectare of beans is then 123 francs.

Lentils, chick-peas, loupins.—Lentils, chick-peas, and loupins are cultivated during the winter, lentils in much greater abundance than the other two plants.

The time and method differ little from those which have just been mentioned for the culture of beans.

Lentils remain in the ground about four months, loupins five, and chick-peas seven months.

They use from 100 to 200 liters of seed per hectare, according to the nature of the soil.

The product of a hectare may be as high as 25 or 26 hectoliters in good land, but the average for Egypt is much lower for lentils. In Upper Egypt it is seldom more than 12 to 13 hectoliters per hectare.

The price of a hectoliter of lentils is on an average 10.80 francs.

Cotton.—Cotton has become since the war of secession in the United States one of the principal crops of Egypt, but the time has passed when the high price of this product enriched the country. It is the most important of the summer crops. It is hardly made except in Lower Egypt; however, it is beginning to be developed in the province of Beni-Souef, to the north of the region irrigated by the Ibrahimieh canal. It is a costly crop, because the time at which it demands the most water is exactly that when the water is lowest in the canals and when the drought is the greatest.

Cotton is sown about the month of April and it is picked about the month of November. The kinds cultivated in Egypt are generally of short and fine fiber.

The land is prepared by three or four workings; then the clods are broken up; they then make furrows in which are placed the seed, at the rate of 75 litres per hectare; then they divide the ground into squares by small dikes and lay out the ditches for water.

Cotton requires eight or ten waterings, or one every fifteen days.

Some days after the new plants have sprouted they clear it out by a second tilling, then four times at least they cut out the bad plants.

The picking is done as the bolls mature. The cotton which is thus obtained is placed in sacks and carried to the gin. Here the fibers are separated from the hulls. For this it is only necessary to place the cotton before two parallel cylinders moving in opposite directions and near enough to draw the fiber without allowing the seed to pass.

The cotton thus obtained is then made into bales and sent to the sea-port, where it is compressed in the hydraulic press before loading on the vessel.

As for the cotton seed, that serves for sowing the second year or is sold to be made into oil.

Finally, the stalks of the cotton plant are used for fuel for steam-engines.

In the first years of the culture of cotton in Egypt they calculated upon a return of 600 to 700 kilograms per hectare, and they still obtain this in the best lands, or in those lands which have not been weakened by summer crops. But, either because the seed is no longer of good quality or the manure given to the ground is not sufficient, the return from cotton is much less to-day than the above indicated amount. This plant besides has to struggle against two enemies which create great ravages. In the first place, the fogs which often rise in the morning, during the months of September and October, prevent the cotton from maturing; and in the second place, a peculiar caterpillar, which destroys the entire crop and against which they have strived almost in vain to protect themselves up to the present.

They can calculate on a mean product of not more than 300 kilograms of ginned cotton per hectare. The crop of 1886 gave 370 kilograms per hectare.

The mean selling price for late years has been 154 francs per hundred kilograms, but this price tends to fall more and more.

A hectare produces on an average 10 hectoliters of cotton seed, which is sold at the rate of 9 francs a hectolitre. Finally, it produces 300 kilograms of stalks per 100 kilograms of cotton. These stalks are worth 54 centimes per 100 kilograms.

Thus the gross product of one hectare sown in cotton is:

	France.
300 kilograms of cotton, at 154 francs a hundred kilograms.....	462.00
10 hectoliters of seed, at 9 francs a hectoliter	90.00
900 kilograms of stalks, at 54 centimes a hundred kilograms.....	4.86
Total.....	556.86

Various crops.—The plants of which we have just spoken are those whose culture is the most extended throughout Egypt, but there are besides others whose production has not been of much importance up to the present. They are principally:

For textiles, flax, which is sown in December and harvested in April; and hemp, which is a summer crop.

For oleaginous plants, lettuce and sesame.

As dye plants, indigo and carthamus, whose flower is used for the dye and the seed for the manufacture of oil.

Finally, tobacco, which is cultivated generally in the autumn after the fall of the water.

II. MANAGEMENT OF THE LAND.

The rotation in the inundation basins is very simple, the land here only bearing one crop a year. They alternate most frequently a crop of wheat with a crop of beans or lentils, or with clover. They sometimes make two crops of wheat in succession, and sow only in the third year barley and the forage plants, such as lentils, beans, vetches, clover, etc. Finally in other regions they alternate wheat and barley with forage plants. In the interior basins, in the low lands easily watered, or on the banks of inundation basins, they alternate crops of sugar-cane and Indian corn in the spring-time, but ordinarily they do not cultivate these crops two years in succession on the same grounds. These crops disappear before the flood, and the winter crop succeeds them.

In the elevated portion of the region of the basins, which are not inundated, as along the Nile banks, they apply, in the large properties, rotations which are used for the lands where irrigation is regularly practiced, and they water them by steam. But for small farmers the culture of cotton and the sugar-cane is too costly and too difficult in this part of Egypt, on account of the great

height to which the water is to be elevated; therefore, they are content to water only the land which borders the river, and they here alternate dourah in the spring and in the autumn with winter crops.

In the region of irrigation for example, in Lower Egypt and especially where the land receives water during the whole year, the alternation of crops almost entirely adopted is a triennial alternation, comprising for the first year the summer crop, the second year a winter crop, and the third year a winter crop, to which succeeds an autumn crop. Thus for the good lands of Lower Egypt they apply the rotation of crops as follows:

The first year, cotton.

The second year, half beans, a quarter clover, and the remaining quarter in the different winter crops.

Third year, wheat during winter, then, at the moment of the flood, corn and dourah, with one cutting of clover after the dourah.

In 1883, for an area of 48,000 hectares, situated for the greater part in Lower Egypt, the administration of the domain of the Egyptian state made a double crop on 7,000 hectares; they then in reality cultivated this year 53,000 hectares. Upon this whole area a proportion of 67 per cent. was cultivated in winter crops and 31.70 per cent. in summer crops.

Thus the product of the summer crops require about one-third of the cultivated surface.

In 1886, according to official statistics, 346,967 hectares were planted in cotton in the whole of Lower Egypt; this corresponds to 30.15 per cent. of the total cultivated surface of this region. The lowest proportion was in the province of Galoubieh, where it only reached 19.79 per cent. This inferiority to the other provinces obtained for Galoubieh because the land here is too high, and because the elevation of water during low water is too costly, and for the province of Behera on account of the water supply in this province.

As to the winter crops, we may have an idea of their distribution in Lower Egypt from the figures given below for the harvest made during the winter of 1884-'85 in the provinces of the Delta proper, Menoufieh and Garbieh, and taken from statistics collected by the inspector of the irrigation of this region:

	Hectares.
Flax	638
Vegetables	2,708
Wheat	136,105
Barley	72,658
Beans	47,838
Clover	79,811
Total area in winter crops	339,758

The total cultivable area being 500,000 hectares, it is seen that the whole of the winter crops occupy 68 per cent. of this area.

In the region of the Ibrahimieh or Ramadi canal, that is to say, the irrigable parts of Upper Egypt, where the cultivation of sugar-cane is very extensive, the ordinary rotation of crops on the five years rotation is thus arranged: First year, the preparation of the soil; second year, sugar-cane; third year, second crop of sugar-cane; fourth and fifth years, winter crops, either wheat, beans, or clover, for the greater part.

In the same places, in irrigated ground where sugar-cane can not be cultivated, the regimen is biennial, wheat and beans alternating for the most part; in certain portions of Upper Egypt lentils and chick-peas partly replace beans. In every case they reserve each year the area necessary for the cultivation of clover intended for forage for the animals.

The Daira Sanieh, which owns 94,000 hectares in the provinces of Upper Egypt, where sugar-cane can be cultivated, raises it annually on 13,000 hectares, about an area equal to 14 per cent. of the total area.

In the northern portion of the Delta, where rice is cultivated, the rotation varies according to the quality of the soil.

Upon bad lands and those impregnated with salt they cultivate rice every year, this crop being considered as a betterment, and the abundance of water it requires produces from time to time a very effective washing of the soil.

When the lands are poor they cultivate rice one year, and the next year, in winter, they plant wheat, barley, or clover.

Finally, when the lands are of good quality, they raise rice the first year, the two following years a summer crop, that is to say, cotton and one winter crop, with an intermediate crop of dourah in autumn, with a rotation every three years similar to that which is mentioned as generally employed in Lower Egypt; the fourth year they return to the rice crop. The summer crops are made either the second or third year.

III. FERTILIZERS.

The water and mud of the Nile are almost the only fertilizers which the soil of Egypt receives. The farmer adds, in fact, few fertilizers, and it may be stated that if he employed them in greater quantities he would increase notably the product of the soil and the quality of the product.

Thus in the parts of the basins where they make only winter crops after the inundation it may be said that the use of fertilizers is unknown. The only manure which is given to the ground consists of the droppings of the animals which graze in the clover fields.

However, on all the lands where they cultivate dourah, and especially on those where the summer crops are made, they spread a little fertilizer, but the quantity is generally too small, and the practice of manuring the land is not sufficiently developed in this country to well indicate the proportion of different materials which produce the best results for the crops.

The fertilizers which are most used in Egypt are the manure of the farms, pigeon manure, and the dust procured from the ruins of old cities.

The farm manures are not abundant, on account of lack of pasturage during the greater part of the year and on account of the necessity which this lack imposes on the farmer of restricting as much as possible the number of animals which he raises.

The pigeon manure is provided by the great number of pigeons which are in the country. The active principals which it contains are nitrogen, phosphoric acid, and phosphate of lime. According to analyses which have been made at Paris by M. Gastinel Bey, under the direction of Payen, 100 grams of this pigeon manure contain :

	Grams.
Nitrogen.....	3.93
Phosphoric acid.....	1.67
Phosphate of lime.....	3.63

The numerous mounds which the traveler sees in passing through Egypt, and which mark the places of ancient cities and villages, furnish two kinds of fertilizers: in the first place, the salt-peter materials, which hold as high as 6.50 grams of nitrogen and potash, and in the second place a kind of earthy fertilizer which contains in 100 grams of material, according to the analyses of M. Gastinel Bey, about—

	Grams.
Nitrogen.....	0.88
Phosphoric acid.....	1.27
Phosphate of lime.....	2.25
Potash and soda.....	2.25

These products, provided by the detritus accumulated by time and atmospheric influences in the ruins of old cities, are carried to the fields in a pulverulent condition, which facilitates the assimilation of their active properties. In the mounds from which they are extracted they are mixed with the débris of stone and bricks. The peasants before taking them away are careful to screen them. They then leave the large materials, only taking the fine dust, which they load into large boxes, upon the backs of donkeys or camels, and then spread over the lands.

Besides the fertilizers which have just been mentioned, farmers employ the ashes of certain plants. They use also, in addition, the mud which is taken from the bed of the canals during dredging.

IV. METHOD OF FARMING THE LAND.

The method of farming the land varies entirely according to the importance of the property.

As in all agricultural countries, the small proprietor cultivates his fields himself. For estates a little more extensive an association is formed between the proprietor and the peasant, the latter

reserving to himself a part of the product. Finally the large proprietor pays the farm laborers their wages in money and sometimes in kind, or he simply confines himself to leasing his lands.

In Egypt the large proprietor generally farms at his own expense. Nevertheless the great administrations of the state, which own a considerable portion of the Egyptian territory, such as the domains of the state and of the Daira Sanieh, have a tendency, more or less, to lease their lands.

The proprietor who farms his lands himself generally has his farm managed by an intendant, having under his orders many agents to conduct the labor in the fields.

With this arrangement the fellahs or peasants who work the land receive wages in money and wages in kind. The price of a day's work is generally 52 centimes for a man, 39 centimes for children. The remuneration in kind consists in one-fourth of the autumn crop—that is to say, of corn or of dourah, the fellah making this crop without money wages. Besides, one-half a hectare of land is allowed to each father of a family to cultivate clover to feed his animals. But they hold back from his wages in money a sum equal in value to the tax on this half hectare. The proprietor irrigates his lands with elevating-machines and compensates himself for this expense by utilizing the manure of the animals to fertilize in part his crop of dourah.

The proprietor whose domain is less considerable, and who does not possess sufficient resources to work it himself, joins with the fellah. In this case the proprietor assumes as his share of expense the cost of irrigation, the seed, animals, and farming utensils. The fellah only furnishes the manual labor up to the complete maturity of the crops. For his labor the fellah receives a fifth of the summer crop, cotton and vegetables, and a fourth of the crop of corn. He has no share in the winter crops. A half hectare of land is also allowed to each father of a family for the cultivation of clover. The picking of the cotton, reaping and winnowing of the winter crops, and the storing of these crops are at the expense of the proprietor. The cutting of the cotton stalks is not paid for.

Sometimes the fellah is only entitled to one-sixth of the winter crop and summer crop, not including clover, and one-fourth of the corn crop. When he furnishes the manure for this latter crop, and the seed, and when he works it with his own animals, he is entitled to one-half the crop. Finally, when he stands all the expense of cultivation and pays one-half the tax, he is entitled to one-half of all the crops.

But the arrangement which is most common is that in which the fellah takes one-fifth of the summer crops and one-fourth the autumn crops.

The most numerous class of farmers always is that of the small proprietors, who cultivate their fields with their wives and children.

In the contracts which are made by the administration of the domains of the state the length of the lease is fixed generally at three years, with the condition of only making on the same land a single summer crop during this period. Sometimes special leases are made for a single autumn crop. In the latter case the fertilizing is at the expense of the renter.

In Upper Egypt the Daira Sanieh also makes many leases for the cultivation of cereals only. The length of the lease is one year. For sugar-cane alone it is three years; for sugar-cane and cereals together it is six years.

The renters sell to the sugar-houses of the Daira Sanieh their sugar-cane at an agreed price.

The Daira most frequently assumes the expense of the labor as far as it concerns the planting of the sugar-cane, rarely for cereals.

In a contract for the cultivation of cereals they exclude every summer and autumn crop. In a contract for leasing, which comprises planting of sugar-cane, they forbid every other summer crop.

The mean price for the annual lease of land rented by the domains of the state in Lower Egypt is about 100 francs a hectare. But these rates are very variable; it is often made higher. In the low regions of the north of the Delta it seldom exceeds 20 francs a hectare.

In Upper Egypt the irrigated lands are always rented at variable prices, which may vary on an average from 200 francs a hectare for the cultivation of sugar-cane to 125 francs for the cereals.

In the basins the price for renting land seldom exceeds 90 francs.

CHAPTER VIII.

BENEFITS RESULTING FROM IRRIGATION

In a country like Egypt, which produces nothing without watering, it is not possible to estimate the benefit derived from irrigation as could be done in a region enjoying a temperate climate, where the rains are sufficient to afford the earth a certain fertility and where the establishment of canals is solely for the purpose of increasing the production and counteracting by constant distribution of water the hurtful effects produced on the crops by irregular atmospheric phenomena.

In Egypt, wherever the water of the Nile does not penetrate naturally or artificially, no cultivation is possible. The water of irrigation gives to the soil here almost its entire value, and it may be said, in a general way, that the value of the fields here depends upon the facility with which they may receive irrigation water.

Thus in the basins the lands which only receive the water of inundation can only raise winter crops; they are therefore of a quality inferior to the lands of the basins themselves, which by their positions in low points or along the canals can produce besides a crop of corn. The lands situated on the banks of the Nile or upon the borders of the canals, which have water the whole year, have also a value greater than these last. And, finally, the best properties are those which always have water at the level of the soil, that is, when they can easily shed the drainage water.

It is quite probable that the ancient Egyptians were not satisfied with making crops by submersion, and that they also practiced irrigation over a notable portion of their property. In every case, whatever may have been the vicissitudes through which the art of watering has passed in this country, from the most remote up to our own times, the first step in the march of progress has been to regulate the waters of the flood under conditions permitting their equitable distribution over the whole country, and allowing them to remain in the basins as long as the requirements of agriculture call for. The second step was accomplished, where inundation did not reach, by canals distributing the whole year, the water of irrigation. The third amelioration was obtained at all points where by raising the level of the water it is possible to reduce or abolish the use of elevating-machines without compromising the fertility of the soil by infiltration.

It being a fact that the *corvée* has contributed in great part to the execution of all the important works of irrigation, it is impossible to estimate the cost of these works and to compare the advantages which the country derives from them with the amounts expended. It is nevertheless interesting, in spite of this, to endeavor to enumerate the benefits which have resulted to such and such a region from the construction of certain works, without occupying ourselves with the pecuniary sacrifices that have been made for the establishment of these works.

Unfortunately, the lack of statistical and official documents in Egypt renders this quite difficult, and it does not allow the results obtained to be presented in a very precise manner.

One of the greatest transformations which this country has undergone during the last fifty years has been the substitution of irrigation in the whole of Lower Egypt and in a considerable part of Upper Egypt for the system of watering by inundation. This is the principal modification in agricultural methods which has afforded Egypt that very remarkable prosperity which has existed for the last few years, and which would exist doubtless still if it had not been the signal for the ruination and waste of the finances of the state. Irrigation has in fact alone rendered pos-

sible the extensive cultivation of the sugar-cane of Upper Egypt and cotton in Lower Egypt, and this latter industry, during the war of secession of the United States of America, at the time when the value of cotton was very high, was found so much developed in the Delta that the country was able to profit largely from the increase in price and to increase notably its wealth.

The extension of summer cultivation in Upper Egypt is due to two causes:—on the one hand, to the advantages which the introduction of steam pumps for irrigation has given to large farms, and, on the other hand, to the creation of canals with permanent discharges.

It is also due to the installation of powerful steam elevating-machines that we have been able to undertake the regular cultivation of sugar-cane in a part of the province of Esneh, where now there are magnificent sugar factories belonging to the Daira Sanieh, and in certain parts of the province of Guirgneh, especially at Farchout, where the large proprietors also raise this product and have built an important factory. In this last place, according to the memoir of Girard, published in the work of the French expedition in Egypt, the cultivation of cane already existed at the beginning of this century, but not more than 3 hectares out of 50 were devoted to it.

In the provinces of Siout, Minieh, and Beni-Souef it is also the employment of steam-engines which has contributed to develop the cultivation of sugar-cane; but it is especially the creation of the grand Ibrahimieh canal which has given it all its scope.

We have seen that the normal discharge of the Ibrahimieh at low water is 33 cubic meters, and that this quantity of water suffices to make summer crops on 42,000 hectares. If all this area were cultivated in sugar-cane, with the five-year rotation adopted by the Daira Sanieh, these 42,000 hectares would correspond to a total cultivated surface of 105,000 hectares, affording annually 42,000 hectares of sugar-cane, 42,000 hectares of winter products (wheat, beans, clover, etc.), the other 21,000 hectares being left at rest. They could make thus 84,000 hectares of crop without counting the crops of autumn corn, which are much more developed to-day than was possible before the construction of the canal, and which may be estimated at one-fifth the total surface. Now, with the cultivation by basins, these 105,000 hectares were annually planted in winter crops, and did not produce summer crops except at certain points exceptionally situated. Winter cultivation is a little more costly by irrigation than by inundation on account of the expense of watering, which is done away with in the latter case, and the expense of labor which is diminished; but the difference is not so very considerable and it does not exceed 4 or 5 per cent. in the real expense of cultivation.

The cost of leasing lands, which in the basins hardly exceeds 90 francs per hectare, may in the irrigated lands be considered as 200 francs per hectare for the cultivation of cane, 125 francs for the cereals, and 130 francs for corn. The total increase of revenue which the Ibrahimieh can produce, supposing the cultivation of cane to be as extensive as possible, can then be calculated as follows:

The present price of leasing would be—

	France.
42,000 hectares of cane at 200 francs.....	8,400,000
42,000 hectares of cereals at 125 francs.....	5,250,000
21,000 hectares of corn at 130 francs.....	2,730,000
Total	16,380,000
While formerly it would have been 105,000 by 90, or.....	9,450,000
Or a difference of.....	6,930,000

which divided among the 105,000 hectares gives an additional value of 66 francs per hectare. Now, as the net revenue of the basin lands does not exceed 100 francs, counting the expense of cultivation and the general expenses of a large farm, and not including the taxes, it is seen that the Ibrahimieh canal has been able to increase by 66 per cent. the net revenue of the lands which it waters.

But it is not always so; the summer crops, for different reasons, are not so extensive as is assumed in the above calculations; thus on the 77,000 hectares, which the Daira Sanieh possesses in the region of the Ibrahimieh, there are now cultivated annually, in sugar-cane, hardly more than 10,000 or 12,000 hectares, or about 15 per cent. instead of 40 per cent. This condition of affairs is

either because certain irrigated lands are not always sufficiently near the factories; or because of the difficulties of the system of distribution, or because some regions, not having water-shed for the drainage, are rendered salt and have become unfit for cultivating sugar cane.

Although the Ibrahimieh canal has thus increased the wealth of the properties which it crosses, it has on the contrary caused certain damages to the inundation basins situated in the vicinity by cutting off their communication with the Nile, and forcing them to receive only the settled water from the upper basins. A few kilometers of canal, or syphons under the Ibrahimieh canal, will again permit of the bringing of the muddy water into these basins, and it is estimated that these works would increase here annually the revenues of the lands by one-fourth, or at least one-fifth.

In the whole of Lower Egypt, in consequence of the suppression of inundation basins, cultivation has undergone a modification not less complete than what has just been mentioned for certain parts of Upper Egypt. At the commencement of this century there were in the Delta two kinds of crops—those of summer and those of winter. But those of summer could only be made on the banks of the Nile or its branches, or on a few trunks of canals with permanent discharges; and besides, for winter crops, since the height of inundation water and the duration of its stand on the land is not sufficient to give a sufficient amount of humidity to the soil, they were obliged to supplement it here by means of artificial waterings. These winter crops in the Delta were then common and needed for maturing, inundation and irrigation.

According to Girard, of the French expedition, the management of 100 hectares of good land well situated in the Delta was formerly arranged in the following manner:

	Hectares.
Clover	25
Wheat	30
Barley	10
Wheat and barley mixed	35
Total.....	100

Of these 100 hectares, one-fourth received summer crops and autumn crops as follows:

	Hectares.
Corn	13
Sesame.....	6
Cotton	6
Total.....	25

At present, as has been said in the preceding chapter, 100 hectares of land in the Delta may be arranged as follows:

	Hectares.
Corn, one cutting of clover, and cotton.....	33
Wheat	33
Beans	17
Clover (half of which was leased to the peasant).....	17
Total	100

The proportion of summer crops, therefore, is now considerably increased.

For the ordinary lands of Lower Egypt, where there is no watering by machines except for two months of the year, below is given the manner in which the present net proceeds of the land may be estimated, cultivated according to the rotation indicated above, and in the case of large proprietries farmed directly by the proprietors:

<i>Expense for an area of 100 hectares.</i>		France.
1. Seed.....		2,900
2. Superintendence.....		2,000
3. Expense of irrigating by machine for two months.....		1,100
4. Feeding of stock during summer at the rate of two head per hectare.....		1,900
5. Pay of workmen for sowing, harvesting, thrashing, etc.....		5,200
6. General and contingent expenses		2,500
Total expense (without including taxes).....		15,600

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Receipts from an area of 100 hectares.

	Francs.
1. Crop of doura on 33 hectares; gross product of 33 hectares at 104 francs.....	3,432
Deduct for the expense of cultivation paid in kind and for housing the crop (about one-fourth).....	852
Remainder	2,580
2. Clover cultivated after doura, 33 hectares at 90 francs	2,580
3. Crop of cotton, not including the cost of ginning, 33 hectares at 550 francs.....	18,150
4. Crop of wheat, 33 hectares at 196 francs	6,468
5. Beans, 17 hectares at 133 francs.....	2,261
6. Clover { 4 hectares fed to stock	640
{ 4 hectares for seed and straw, at 160 francs	
Rented to the peasant 8.50 hectares at 100, equal to the tax.....	850
Total receipts	33,919
Then we have for the 100 hectares thus cultivated, receipts.....	33,919
Expenses.....	15,600
Difference.....	18,319

which represents about a net product of 138 francs per hectare, not counting the payment of taxes.

To compare this revenue with what the land in the Delta could give, if the method of basins yet existed there, let us suppose the property under such favorable conditions that it could be arranged with one eighth of its area for summer crops; this is evidently a better condition than that averaged at the beginning of this century, but which is, nevertheless, given in the works of the French expedition in Egypt as a normal arrangement.

If the crops made on this property are the same as those which have been considered in the preceding examples, we would have for the 100 hectares, 13 hectares of corn, doura, and cotton, 53 hectares of wheat, and 33 hectares of beans and clover; this would give then as follows, the expense of 100 hectares:

	Francs.
1. Seed.....	2,600
2. Superintendence.....	2,000
3. Irrigation by machine during at least two months for the summer crops and for doura	800
4. Feeding the stock during the summer	1,900
5. Pay to laborers, etc.....	3,000
6. General expenses	2,500
Total expense	12,800

As to the average receipts, they would be as follows:

1. Doura, 13 hectares at 78 francs.....	1,014
2. Clover, 13 hectares at 90 francs.....	1,170
3. Cotton, 13 hectares at 550 francs	7,150
4. Wheat, 53 hectares at 196 francs	10,388
5. and 6. Beans and clover on 34 hectares as in the preceding example.....	3,751
Total receipts (not including taxes)	23,473
Thus the total receipts would be.....	23,473
The expenses.....	12,800
The difference.....	10,673

We would then have a net produce per hectare of about 107 francs.

By the substitution of the irrigation system for the basin system, the net revenue per hectare is then raised to 183 francs; this is an increase of 70 per cent. over the results given by the ancient

method of watering and of cultivation. On the lands upon which it was not possible formerly to make summer crops, and which also could not receive inundation water every year, the benefits derived from the permanent supply of the canals are much more considerable; they would be still greater throughout the whole of Lower Egypt if the farmer would determine to refresh the soil from time to time by the judicious employment of fertilizers.

The considerations developed in the preceding chapter on the subject of dredging and discharge of the principal canals have already shown of what importance to the prosperity of the country is the attention given to the repair of the canals and works of skill, and how much trouble and continuous attention these repairs require in consequence of the want of consistence of the soil and the quantity of mud held in suspension by the water. A few figures will show more clearly the results which can be obtained without creating new works of irrigation by merely maintaining in good condition those which exist.

In 1879 the clearing of the canals had been very much neglected in the province of Keneh, where the old system of basins still exists. Although the level of low water was sufficiently high, this year there were 5,800 hectares cultivated in summer crops. In 1881, without any new arrangement but the simple labor of dredging, they were able to devote to these crops in the same provinces almost 15,000 hectares, although the level of low water was at Assouan 1.79 meters less than in 1879.

Here is another example not less striking. The quantity of sugar-cane cultivated by the Daira Sanieh is nearly proportional to the quantity of water which it can distribute to the plantations. Now, in 1882, the year in which the late troubles occurred in Egypt, when the low water of the Nile was almost as low as in 1885, the Daira cultivated 11,700 hectares of sugar-cane, while this latter year it cultivated 15,700 hectares, or an increase of 34 per cent. This considerable increase of cultivation was due almost entirely to the better maintenance of the Ibrahimieh canal, and also to a more judicious distribution of the water of this canal. In the same manner, by giving to the Bahr Youssef, derived from the Ibrahimieh canal, the proportion of water which ought to return to it, and without doing, so to speak, any other work than the maintenance of the Ibrahimieh canal at a normal depth, they were able in 1886 to cultivate in Fayoum 22,000 hectares in summer crops, while in 1880 they only obtained 6,500, and in 1882 only 13,000.

These enormous variations in the extent of area given to the different crops show well the changeable value of irrigated lands. The product of these lands may vary in large ratio, not only when the maintenance of the works are neglected, but even from one year to another, so that the engineer should devote more or less attention to the maneuvering of the works and to the clearing out of the canals.

Agriculture would realize great benefit if it were possible to always give water to the peasant at the same level as the land, so that he would only have to open his inlet to water his fields; but this is far from being the case everywhere. At present this result is attempted in Lower Egypt, on the one hand by damming the waters of the Nile by the great dam at the point of the Delta, and on the other hand by adopting the proper rules for the regulating works established along these canals.

The first important result obtained by a more complete although still temporary use of the dam of the Delta has been to render the cultivation in Lower Egypt, in the provinces profiting by the action of this work, almost independent of the height of low water of the Nile.

Thus, while it was formerly known that the low stages led in Lower Egypt to a diminution of the product of summer crops equal to 100,000,000 francs, in the year 1884, when the low water of the Nile was very low, the crop of cotton in Lower Egypt was estimated at 20,000 tons more than in 1879, the year when it was greatest up to this time, and when the low water at Assouan was 1.39 meters higher than the low water in 1884. Nevertheless, the effect of the dam does not extend to-day over more than 700,000 hectares, 500,000 hectares in the Delta proper and 200,000 hectares in the provinces of the east.

This difference of 20,000 tons, representing a value of 30,000,000 francs, was due mostly to the fact that the dam of the Nile furnished water to Lower Egypt in 1884 at a level almost 1 meter higher than had been previously obtained in the average year.

In 1885, when the level of the pool of the dam was still further increased by nearly 1 meter, the area planted in cotton in Lower Egypt was still greater, but the cotton-worm and fogs caused such ravages to the crops that the production was lower than that of 1879.

The raising of the Nile by the dam has also allowed the suppression of numerous steam-pumps, and thus saved to the farmer considerable expenditure.

The few facts mentioned above show how valuable are the improvements gradually being made in the system of irrigation in Egypt, and how important it is for this country to pursue unremittingly the placing of these improvements in working order, that they may be able to obtain from the land with economy all the profit of which it is capable and which is expected of it.

CHAPTER IX.

IRRIGATION OF EGYPT CONSIDERED IN REFERENCE TO LAWS AND REGULATIONS — METHOD OF THE LANDED PROPRIETORS.

It might well be believed that Egypt, renowned for the wisdom of its ancient inhabitants and the antiquity of its irrigation, had preserved in its traditions a complete patrimony of laws and customs relating to the use of the Nile water. However, nothing of the kind exists. Thus one finds in Egypt neither special regulations for the use of the water nor particular jurisdiction for matters relating to irrigation, or penalties provided for offenses in the abuse of the water. The fact is quite astonishing, and deserves notice. Such an omission is, in fact, strange in a country which not only owes its existence to the waters of the Nile, but where Arabian rule has been established for many years, which left in Spain such remarkable specimens of rules and regulations for irrigation.

The fact which, as well as the absence of all special legislation, characterizes the system of Egyptian irrigation is the large part which the Government takes in the execution and maintenance of the works and in the distribution of the water. The Government, in fact, has assumed the task of distributing the water of the Nile, not only in the principal canals, but also, we may say, to the heads of the most remote trenches, and it employs, to assure this service, the resources in money or in kind which it obtains in taxes and from the *corvée*.

It is doubtless very natural that it should be the state which fixes the dates of opening and shutting the inundation basins, as well as the discharge of their inlets and works of drainage, according to the variable circumstances of the rising and falling of the Nile; that it should regulate, according to the regimen of low water, the pool of the great dam of the Delta; that it should distribute amongst the principal arteries, which have their inlets on the river itself, the waters of irrigation; that it should take the necessary measures for the superintendence and repair of the great canals and embankments. It is hard to conceive how it could be otherwise; these are indeed the public services which the government can not delegate to individuals or to associations or proprietors; the entire country requires that a single individual authority should regulate the general distribution of the water of the river, the only source of wealth of the inhabitants, and protect the cultivated lands from inundation. The action of the Egyptian Government does not stop here; it ramifies throughout all the secondary branches; almost all the canals, whatever the degree of their importance, are public property and belong to the state; those which are exclusively under the charge of individuals form a very small portion of the whole, and in practice a very well-defined limit does not always separate these latter from those whose repair and construction are in charge of the Government. The only peculiarities which now distinguish the different kinds of public canals according to their importance, is that they are constructed and maintained by the *corvée*, either of many provinces or of a single province, or of a single district or one or more villages, and still this distinction tends to disappear in proportion as the state uses the revenue to free the *corvée* and execute for cash the part of the work which falls to the population.

As to the distribution of the water amongst the different branches of the canals, as well as for the secondary canals, it is entirely in the hands of the Government agents; they distribute the water as they please, taking account of the condition of the crops and the circumstances which may cause a variation of the distribution; there are no laws or regulations to give to any particular point a determined portion of the discharge of a canal, or to maintain in it a fixed level for the surface of

the water. On the other hand, the farmer enjoys the greatest liberty in opening the ditches or making inlets in the banks of the canals, and in abusing the water which flows across his land. No rules exist for regulating the discharge; no ratio is established between the surface cultivated and the dimensions of the works of inlets. Under these conditions the large proprietors have evidently great facility for monopolizing the water for their own profit to the detriment of the small farmer.

It can be seen under such a regimen, as arbitrary on the part of the Government, as irregular on the part of individuals, how difficult it is to avoid waste, and how defective is the distribution of the water. Certain canals too full inundate the low lands; in others, on the contrary, an insufficient supply does not allow all the riparian lands to be cultivated. The only right which proprietors have who are subject to damages of this nature is to appeal to the authorities, and if from one cause or another satisfaction is not given them, and the land is thus left arid or transformed into marshes and can not be cultivated, they are entirely or partially relieved from tax. This is the only compensation which can be made to farmers; the Government, recognizing that it has not furnished the means to cultivate, renounces the taking of the portion of the crop which belongs to it.

To resume: on the one hand the Government assumes all authority over irrigation, and on the other the individuals are subjected for the use of the water to no special regulations. Two principal causes have contributed to create this state of affairs and to develop this kind of communism in the utilizing of the beneficent waters of the Nile. One relates to the system of inundation basins, and to the method by which these basins have been transformed into irrigable lands; the other, more general, relates to the method of the landed proprietor himself.

In a system of basins of inundation individual enterprise is necessarily done away with, and precise regulations for the use of the water by individuals are entirely useless. It is the unity of interests which causes the necessary measures to be taken to bring water and to maintain the level and to drain it afterwards. The proprietor has no special trouble to give himself to inundate his lands, no trenches to dig, no dikes to raise; he is only obliged to contribute in money, workmen, or his labor to execute the works necessary for submerging the entire basin. When Mehemet Ali, in the first years of this century, commenced to dig irrigation canals in the lands formerly arranged in basins, he only had to aid him in his proposed agricultural revolution a population little enlightened and deprived of individual enterprise, who often saw with regret the abandonment of the traditional method of cultivation in the country. He could not rely on them to dig rapidly the secondary canals, therefore he confided to the Government engineers themselves the direction of the whole of the details and labor, and in order not to compromise the work by the apathy, laziness, or bad will of the peasants, he took, himself, in the name of the Egyptian Government, measures to carry the irrigation to the very limit of the land of all the proprietors without asking them for any more help than their presence in the *corvée* charged with the work. After having constructed, itself, in this manner, all the canals necessary, the state was naturally charged with maintaining them. It is thus that, under the name of the government of the province, of the district, or of the community, it finds itself at the head of a whole net-work of canals, including also numerous branches of little importance. On the other hand, the systematic substitution of irrigation for the old basins does not date far back, and it is very astonishing that since the beginning of the century laws for the use of water have not been codified.

But although these considerations explain partly the condition of irrigation in a legal point of view, they should not, however, be regarded as absolutely general causes. There has been, in fact, from all antiquity in this country, and especially in the Delta, portions of the territory which have been irrigated, although we find no traces of a perfected regulation of the watering. It is in the method of the landed proprietor himself that it is necessary to look for the origin of this state of affairs, and on this account it is interesting to enter into a few details of the history and transformation of landed property in Egypt. We find very complete information on this subject in an excellent book upon "Landed Property in Egypt," published recently by his excellency Yacoub Artin Pasha, under secretary of state to the Egyptian ministry of public instruction, and it is from this work that the summary remarks which follow are principally taken.

It seems that from the most remote times landed property had not existed in Egypt in the sense in which we understand the word. Without going beyond the Arabian conquest the Mussul-

manish historians write that in this epoch "the farmer did not possess property in the soil which belonged to the community and by extension to the sovereign, that is to say, to the state." The commune formed, so to say, the territorial unit; this latter, as a whole, had the usufruct of the land. And in fact the conquerors, who continued to levy taxes "as they had been established by the Greeks," fixed the tribute to be paid by the commune according to the number of inhabitants; and if in the commune the tribute was not paid, they divided the sum among the lands of the commune and divided these amongst the inhabitants of each portion in proportion to their means. If at the time of this division quarrels and disputes arose which were impossible to settle, they distributed the lands of the commune in equal portions among all the inhabitants.

Also at the same time the conquering Arab chiefs created a more complete method of holding the land. Of the land belonging to the Greeks, the last occupants of Egypt, some were given to villages; but others were distributed to a few privileged persons, under the title of proprietor, and exempted from taxes. There was not up to this time anywhere a true proprietor, because although the land could be transmitted to the heirs of the holders their rights were very little respected by the sovereigns of the country; each of these considered himself always free to dispose of the land and to take it from the actual possessors to give it to his partisans.

Later, similar property rights were conceded to factors who were charged with collecting taxes in the commune; but in all cases, whether the lands were exempt from taxes and distributed either for a reward or as an acknowledgement of service rendered, or whether they were conceded as usufruct to the Egyptians and loaded with tribute, it was always the sovereign who remained the true proprietor.

This system lasted, with some slight modifications, until the beginning of this century, and it may be believed that during this long period of time the communal rule of property, its instability, its insecurity, and especially its character of usufruct, had contributed considerably to the development of a normal system of irrigation based on the rights and interests of individuals.

The principal care of the sovereigns of Egypt was, in fact, much more the return of the taxes than establishing the prosperity of the country on a solid basis by improving the distribution of water and by wise legislation.

It was about 1813 only that Mehemet Ali commenced to enter with vigor into the accomplishment of agricultural reform. After having made, with the very imperfect means which he possessed, a general survey of the whole cultivated surface of Egypt, he distributed the lands of the communes to the inhabitants themselves of the villages, so that each cultivator old enough to work had nearly an equal portion. This distribution was made throughout the whole of Egypt, and the portion allotted to each person was from 1.25 to 2 hectares. The chiefs of the villages received, to recompense them for the service which they rendered to the state and to the commune, a portion exempt from taxes. It is from this division of land that we should trace the original parceling out of the agricultural properties, a parceling which the Mussulmen laws on inheritance only increased.

The holders of the land distributed in 1813 only had the usufruct, and although the land was inscribed in their names on the survey register it was always the commune which was responsible for the tax, and also, up to a certain point, all the communes were liable in this respect, and the tenant who could not pay his quota was deprived of his fields. Nevertheless the owners of the lands of the villages acquired, little by little, those rights which constitute the true rights of property; thus the right of willing was granted to them in 1846, and the right of inheritance during 1854. Besides, in 1858, the lands which had been allotted as exempt from taxes to the chiefs of villages were taken away from them and distributed to the inhabitants, to avoid the abuse of power and persons which most frequently obliged the unhappy fellah to cultivate this property without remuneration.

At the same time that by this division of lands among the peasants he was preparing the basis for landed property, Mehemet Ali distributed to individuals uncultivated territory not comprised in the surveyed lands, and which were exempt from taxes to compensate for the work necessary to place them in good condition. In 1842 he granted to the owners of these lands the right of disposing of them as their own property. He contributed thus to extend the cultivated surface

of the country, and added many great domains to those which had been formed by the donations made in the preceding reigns.

Landed property was not really conceded in a general and definitive manner in Egypt until 1871. At this epoch the Khedive Ismail Pasha, wishing to make up for lack of funds, granted, amongst other advantages, the absolute ownership of his ground to the possessor who would pay in advance six years' taxes. The law, which did not produce the financial results expected, was abolished, then re-enacted and rendered obligatory, and finally definitely abrogated by the decree of the 6th of January, 1880; but this decree, and the law of liquidation which followed, recognized the right of property in the lands which had paid, entirely or in part, the advance tax. Under these conditions almost all the land of Egypt has become land with the full rights of property.

Thus the right of property is very recent in Egypt. It was not really constituted when Mehemet Ali undertook the execution of his irrigation works, and this is what explains how this great reformer was led to consider the whole country as his vast domain, of which he was himself proprietor, and how he provided, in the name of the state, for the population of the provinces, districts, and communes, for the construction of canals, great and small, which became by this fact public property.

Unfortunately the farmer, to obtain the real title of property and to assure these rights, must consent to heavy sacrifices. Each concession which the sovereign makes to him is in consequence of an increase of tax, and the charges which weigh him down are to-day so heavy that he can hardly make head against them. Thus the best lands of the villages pay almost as high as 107 francs tax per hectare in Lower Egypt, and 94 francs in Upper Egypt. As to the lands which were originally conceded with exemption from tax, they pay, according to their quality, from 10 to 60 francs per hectare in Lower Egypt, and from 10 to 41 francs in Upper Egypt. Besides these taxes in money, the farmer has to furnish the tax in kind for the *corvée*, and to pay in certain cases special taxes; thus, for example, the proprietor who uses the waters of the Ibrahimieh canal, dug by the *corvée*, pays a tax which amounts in all to about 850,000 francs for an area which does not exceed 26,000 hectares, deducting the lands of this region which belong to the state.

Although the Egyptian has purchased at this high price his rights of property in the soil, and although finally free from the bondage with which he was long oppressed, many drawbacks still remain in many parts of the territory to the free exercise of individual enterprise and to proper agricultural development. These obstacles have brought about the notable condition that all the area of Egypt is either farmed by the state itself or transformed into holdings, generally badly administrated. The existence of great quantities of mortmain land obtains in Mussulmen countries, and it is the consequence of religious laws. As to the farming by the state of considerable domains, it is obligatory on account of the financial disasters which have attacked Egypt for the last ten years. The Government is obliged, in fact, to appropriate and administer on its own account the great properties which the Khedive Ismail Pasha and the members of his family had acquired and which became pledges in the hands of the creditors of the state.

The two administrations charged with the farming of these properties are the Daira Sanieh and the administration of the domains of the state.

The Daira Sanieh has especially in charge the lands of the state situated in Upper Egypt and the large sugar factories which are established in this region. Thus it farms:

	Hectares.
In the region of Esneh.....	20,700
In the region of the Ibrahimieh canal.....	84,500
In the region of Fayoum	32,200
In the region of Lower Egypt.....	74,600
Total.....	212,000

of which 21,000 are uncultivated in Upper Egypt, and 54,000 in Lower Egypt. As to the domains of the state, their property is more especially in Lower Egypt. It comprises:

	Hectares.
In Upper Egypt.....	40,900
In Lower Egypt.....	137,900
Total.....	178,000

Of these, 33,000 are considered as uncultivable.

Thus one-fifth of Egypt is owned by the state and farmed by it, not counting all the lands called free, more or less cultivated, which belong to it also, and which are sold to any one according to requirements.

In the situation of the country resulting from this arrangement, with a system of ownership badly established and continually changing, with so great an extent of land in the hands of the princes of the state, with so unlimited an interference by an absolute government in whatever concerns irrigation, it is evident that the practical and rational regulation of watering could not be established up to the present time.

At present every act of dereliction or dispute relating to irrigation is subject to the ordinary tribunals composed of three courts—summary justice, the tribunal of first hearing, and the court of appeal. In addition, the laws and rules on the subject are most insufficient and incomplete. Egypt still lacks a code for irrigation, whose elements do not exist in the new government, and whose need is nevertheless felt more and more urgently in proportion as the ownership is better settled and justice rendered according to the most strict principles.

It is fifteen years since the Government felt the necessity of creating a special administrative organization to regulate everything which concerns irrigation. A law was even promulgated to this effect, called the law concerning agricultural councils and regulating of dikes and canals. It comprised at the same time a law on the duties of the administrators of provinces and of the engineers. The spirit of this law is clearly indicated in the considerations which precede the section, and which are given below:

It appears proper to the privy council that the agricultural councils should be organized in a permanent manner that these councils should examine the projects of public, communal, and individual works, control expenditures, designate for each commune the number of individuals which execute the works, and that the councils ought to supervise the execution on the spot; that the members of these councils should be chosen by election by the inhabitants of the commune; that there should be elected one for each *arrondissement*, and their duties performed in turn; that there should be required of these councils the constant watching and amelioration of agriculture, and the establishment of fundamental rules for the distribution of water, to be followed in the works of drainage or dams, and works intended for a change in level of the canals, ditches, outlets, etc.

The apparent object of this law was, as may be seen, to obtain a kind of decentralization of the service of irrigation by confiding its direction to the representatives of these councils; the real end was perhaps solely to relieve the treasury of the greater part of the expense of irrigation by causing to be assumed, by those interested, the expense resulting from the decisions made by their representatives assembled in council.

The idea was good in itself, and it might have been the germ of a complete and fortunate transformation of the system of irrigation if it had been formulated in a more practical method, and if the country had been able to comprehend it and to recognize what advantages there would have arisen if the control of irrigation in Egypt were in the hands of the proprietors themselves. In fact, although this law has not been repealed, and although it has been added to the new Egyptian code, to be applied by the courts, most of the articles which it contains have never been placed in force for a single instance; in practice it is a dead letter, the councils of agriculture of the provinces are only convoked to determine the labors incumbent on the *corvée*, as has been shown in a preceding chapter, and the agents of the state regulate almost as they choose the works, canals, and the distribution of water.

It is therefore unnecessary to stop to examine this law for the agricultural councils which has never passed into the domain of application.

In reality, legislation on irrigation in Egypt comprises only a few articles of the code, some general rules, and some ancient customs, their enumeration will be short.

Use of water.—The law applicable to individuals comprise the following principal prescriptions referring to irrigation:

The tribunal of summary justice stands as a last resort up to 260 francs,* and is subject to appeal for amounts above this sum, and, whatever may be the amount of the motion, decides actions for damages to fields, fruits, and crops, either by man or animals, which are connected with the use of water. * * * (Art. 26, Code of Procedure.)

* These sums and the amount of damages are indicated in the tax laws and regulations in piasters and Egyptian pounds.

The extent of the right of using the water of the canals, constructed by the state, is proportional to the land to be watered, except as it is regulated by the laws, decrees, and rules on the subject. (Art. 32, Civil Code.)

Each person must allow, through his own lands, the passage of water necessary to the farthest end of the outlet, on the payment of an indemnity previously determined by the tribunal, which will determine, in case of dispute, the works to be made for the establishment of the passage, in order that it will be as little damaging as possible.

But the proprietor who waters his land by means of machines or canals can not oblige the lower bottoms to receive his water. (Art. 33 of the Civil Code.)

The public domain of the state is imprescriptible, indestruable, and inalienable. The Government only can dispose of it by law or by decree. It comprises the rivers and navigable streams and canals whose maintenance is in charge of the state. (Art. 9 of the Civil Code.)

Belonging also to the domains of the state are the arrangement of water-courses, public works, and generally all the works carried on by the communal right, attached to the property of the public domains, or resulting from laws or decrees issued with reference to public utility. (Art. 10 of the Civil Code.)

Whoever, by the rupture of dikes or in any manner whatever, shall have caused malicious inundation, shall be, according to the amount of damage, condemned to penal servitude for a time or for life. (Art. 334 of the Penal Code.)

Whoever shall have voluntarily destroyed, overturned, or damaged in any manner whatever, in part or in whole, bridges or dikes belonging to another, shall be condemned to imprisonment from two months to two years and to a fine equal to one-quarter of the repairs. (Art. 306, Penal Code.)

Whoever shall not conform to an administrative regulation shall be punished by a fine of from 1.30 to 6.50 francs whenever the regulation does not prescribe the punishment for its infraction. (Art. 341, Penal Code.)

Whoever shall have cut down the public roads or other places designed for public use, or whoever has appropriated them, shall be fined from 13 to 26 francs and punished with from one to six days' imprisonment. (Art. 343, Penal Code.)

The code applicable to foreigners residing in Egypt contains almost the same articles.

Confiscation for public utility.—The state has a right to confiscate private property for works of public utility; but the procedure of confiscation is not provided for by the Egyptian Government as to natives, and that which is provided by the code applicable to foreigners is not practiced. In fact these affairs are conducted frequently as follows:

The declaration of public utility is made without the necessity of proceeding to previous inquiry, by virtue of the decree of the Khedive. The notables, designated by the administrator of the provinces in which the works are executed, meet then and estimate the damage arising. If the interested party accepts the valuation thus made, the state pays him the amount agreed upon; if not, the affair must be carried before the tribunal, but it is seldom that the indemnity to be paid on account of confiscation is not arranged amicably between the commission of notables and the proprietor.

For the lands which have become the complete property of the possessor by the application of the different laws of property the owner of the confiscated ground is entitled to an indemnity in kind, or in lands, equivalent to the amount of damage which has been caused.

As to the lands which, not having paid their advance taxes in pursuance of the law of 1871, have remained on the hands of the occupants in usufruct, they are only entitled to a diminution of taxes for the parties whose lands are confiscated.

Most of the land, at the time of the establishment of the great canals of irrigation and dikes, constructed in the first half of the century, were under this latter regimen. Thus these works have not caused an actual confiscation but a simple diminution of taxes, and even in many points the area occupied by these canals and dikes has not been lightened in taxes, and still regularly pay the tax.

The law for the territorial property of 1858, modified and published in 1875, provided always, in favor of the tenants who had been deprived by the confiscation of their means of existence, a reparation for the damage caused more complete than the lessening of the tax. The law, in fact, gave to the Government the right to give to these tenants lands taken from free lands, or lands abandoned by their villages or another neighboring village.

Regimen of the property which borders the Nile.—There are often on the banks of the Nile, between the protection dikes, low lands which are sown as the waters fall, and whose cultivable surface varies each year with the level of low water. Every year the cultivated portions of these low lands are measured, and they apply the tax to these according to the area of crops carried.

The territory thus comprised between the dikes of the Nile is considered as forming a part of the bed of the river, and is subject to the control of the agents of the ministry of public works,

who have the right here to forbid any dikes, or any construction or establishment of a machine capable at any time of obstructing the force of the water and turning the current out of its normal direction. The Egyptian code stipulates only that alluvium brought in large quantities by the river belongs to the riparian owners (Art. 60 of the Civil Code); but when the Nile, in consequence of a change in its course, carries away a portion of high land along its banks and creates in the middle of its bed new islands, it is the law of territorial property, which has already been mentioned, which regulates the lands displaced or islands formed in the following manner:

First. If the movement of the water leads to a loss in the high lands, or in the commune, and when it forms by accretion a bottom connected with the commune subject to loss, although adjoining at the same time to other lands, this bottom shall serve to replace the loss of land, and in case of an insufficiency the portion not replaced will be relieved of the taxes against it. If the bottom exceeds the area of the land lost the case will be subject to adjudication by public auction, to which the inhabitants of the commune connected with the bottom shall be called. If the bottom does not join the commune which has undergone loss, but another commune not damaged, it will be sold at public auction and allotted to the bidder offering the most, and will form part of the territorial area of the commune.

Second. If an island or islet is formed in the middle of the stream, between the sloughs, and when the current has attacked only one side of the high riparian lands subject to taxes, the ground lost will be relieved from the charges which affect it, according to the amount lost, and the island or islet will be sold and awarded to the highest bidder among the inhabitants only of the commune situated opposite the island or islet, and will be an integral part of the territorial area of the commune of the buyer.

Third. If the island has been formed without loss to the riparian lands subject to tax, it will be sold and awarded to the highest bidder among the inhabitants of the commune situated opposite the island, and will be added to the territorial area of the commune of the bidder. The portion of this island which may afterwards be removed by the water will be, according to the amount of surface lost, subject to a relief from tax. In the case, on the contrary, when an increase may have taken place, it will be by the formality of auction conceded to the buyer of the island, subjected to the same conditions as the original award.

As has very justly been remarked by Yacoub Artin Pasha in the work cited above, this law, which is very vague, is the only one which regulates the rights of property along the banks of the Nile. This question, however, in consequence of the long course of the river, is very important. It has given rise, in fact, to continual litigation on this subject, either between communes or between the taxable riparian owners, and while awaiting for a more complete and better defined law to regulate this matter the administration is obliged to supplement the insufficiency of legislation by measures taken without fixed rules, and to defer to usage and custom in each locality.

Relief from tax.—It is probable that from the greatest antiquity, whenever land has not been inundated by the Nile, and remained from this fact unproductive, the Government has allowed it a relief from tax for the barren years.

The Arabs had even established a mean scale of tribute to be paid according to the height which the flood reached on the nilometers. This explains the attention which the conquerors of Egypt have always paid to the construction and repair of these nilometers.

At present the tax is fixed, but when it is plainly shown that land could not be cultivated for want of water, the Government sends to these places, on the demand of the proprietors, a commission composed of functionaries from the ministry of public works, finances, and the interior. This commission estimates the damages caused by the lack of water, and the Government allows generally a relief from taxes according to the result of this inquiry. In Upper Egypt relief from taxes is still allowed each year, because with a system of basins it is easy to ascertain whether certain lands have been reached or not by the level of the flood; but in a region of irrigation, where the canals receive more or less water the entire year, conclusions are much more difficult to arrive at, and a relief from taxes is more rarely granted.

Various regulations.—The principal regulations in regard to the *corvée* and to the establishment of elevating-machines along the Nile and canals have already been mentioned in the chap-

ters which treat of the maintenance of the canals and elevation of irrigation water; it will be unnecessary to return to this matter.

The guarding of the dikes of the Nile.—The decree of the 6th of August, 1885, has regulated as follows the guarding of the banks of the Nile during the flood:

All the inhabitants who are subject to the *corvée* by the decree of the 15th of January, 1881, are also charged with guarding the dikes of the Nile during the flood.

On the 1st of January the ministry of public works designates for the provinces the points which ought to be guarded and watched; also the number of men which should be furnished for this purpose.

The assembly meets annually, on the 15th of January, in each province, presided over by the administrator of the province, and having for its members the chiefs of the villages and districts and the chief engineer of the province.

The president communicates to the assembly the instructions given by the ministry of public works relating to the number of men to be furnished for the service of guards, and the assembly distributes this number among the districts and villages.

Each chief of a village must send to the administrator of the province before the 25th of January a list of the names of the men whom his village should furnish, and who are divided into two contingents.

The men of the first contingent repair to their posts on the 1st of August, and the second contingent on the 1st of September; the posts guarded are only abandoned by order of the ministry of public works.

The assembly of each province chooses four notables, who, presided over by the engineer of the province, form a commission to judge the delays and delinquencies charged against the village and against the men called out.

The penalties applied are as follows:

Every chief of a village or district, or any notable who shall have neglected to furnish the number of men due from his section, and who shall not have repaired to the post which he had to guard, or who shall have abandoned his post without authority, is within twenty-four hours tried by the commission and condemned to imprisonment of from twenty days to three months and to a fine varying from 52 to 520 francs. The culprit can also be entirely pardoned, if the commission judges it proper, without prejudice to the interests of the damaged party, the latter being able to reclaim damages from him in cases where damages have been caused by the fact of this negligence and in consequence of the desertion of his post; he is immediately replaced.

This decree contains the first attempt to establish a special jurisdiction, although in an indirect manner, for irrigation. It is still too recent to be able to judge the results of its application.

Decree of the 25th of January, 1886, relative to the penalties for disobeying the regulations in regard to the corvée.—Up to the present time the only penalty applied in fact for disobeying the regulations in regard to the *corvée* was merely corporal punishment, and especially the lash. The decree of the 25th of January, 1886, had for its object the establishment, by its requirements of the special jurisdiction, which is the same as that which had been fixed by the decree of the 6th of August, 1885, for the guarding of the Nile dikes. The commission constituted by this latter decree was also called upon to try the delays and delinquencies charged against the chiefs of villages and districts and against the men in all the labors of the *corvée*, and the penalties provided are as follows:

Every chief or notable who has neglected to furnish the number of men due from his section, or who has not repaired to the post where he should work his men, or who has quitted his post without authority, is condemned by the above-named commission, within the next twenty-four hours, to an imprisonment of from ten to thirty days, or to a fine of from 26 to 130 francs; he may also be totally relieved of his duties. Every man who fails to respond to the call or who deserts his post is immediately tried by the commission and condemned to a fine of 13 to 26 francs, and to the performance of the labor which is allotted to him. Whenever he is not in a position to pay the amount of the fine he will be held at labor to a value equal to the amount of the fine, at the rate of the daily pay given to the workmen at the place where his labor is performed.

They have hardly had time yet to apply the requirements of this decree, which will remain perhaps a long time before being admitted into the method of the country.

CHAPTER X.

CONCLUSIONS AND PROJECTS.

From all that precedes, it results that Egypt is not an exceptionally fertile country; it owes in a great measure its ancient reputation for fertility to the same causes which have always given celebrity to the oases of very small extent, or to the cities of little importance, built in the midst of the desert. As a few of these oases and the cities strike the imagination of the traveler who sees them after having crossed sandy and arid regions, so the valley of the Nile, bordered on its two sides by uncultivated solitudes which extend over indefinite space, and cutting through the desert with a narrow band of cultivable land, appears to the eyes of the people who inhabit it as the most complete type of fertility of soil; nevertheless the product of the crops of Egypt indicate in no manner a soil of special richness.

What has especially contributed to attract to this country the attention of nations, is the method by which the inundation waters permit the fellah to obtain each year, almost without labor and without trouble, the various crops under a sky without rain.

But although the basins of submersion form truly the traditional system of Egyptian agriculture, the practice of irrigation on a vast scale is in this country of very recent origin; for this reason the methods are not yet well planned, and there did not exist, up to the present, rules properly established and sanctioned by long usage, for the employment of the water for irrigation, for the rotation of crops on irrigated lands, for the drainage of the soil, and generally for everything which pertains to irrigation. Progress should evidently lead, at the end of a certain time, in the whole of Egypt, to the substitution of irrigation for the system of basins, which, while requiring much less manual labor for agriculture, gives on the other hand products less valuable and less abundant. But, on the other hand, it has been seen how many difficulties and expenditures the maintenance of an inlet work of a canal of irrigation gives rise to, and how the annual filling up of the principal arteries renders precarious the watering of entire regions. Therefore, in every project of irrigation the Egyptian engineers ought to occupy themselves, before everything, in establishing and organizing the regimen of the canals under such conditions, that the deposits of mud will be kept down as much as possible, so that the maintenance of them may thus be rendered easy and economical.

The principal precautions to be taken to obtain these results are those which are observed in all countries where there are rivers with sedimentary waters and movable beds, but they acquire a vital importance in the valley of the Nile, where the two characteristics of mobility of bed and turgidity of water are particularly developed. They can be summed up as follows:

The number of outlets on the river banks must be diminished as much as possible; because it is in the works at the head of the canal that the heaviest materials are deposited, in consequence of the constant diminution of the velocity which is here generally produced, and it is here that the dredging is most difficult to execute; besides, the works of inlets are costly to construct and difficult to protect against the action of the floods, on account of the little cohesion of the subsoil. It is by the application of this method that the dredging in the province of Menoufieh has been notably reduced; it has sufficed for this to close the inlets from the Nile of the principal canals

and join these with the Rayah Menoufieh, which thus becomes the only canal draining directly from the Nile the water intended for feeding the whole province.

The inlet work must be established as near as possible to the ordinary location of the current of the Nile; thus every year considerable dredging is necessary to keep open the inlet of the Ibrahimieh canal at Choubrah, because this work is almost 500 meters distant from the mean current of the river; while on the contrary the lock at the head of the Mahmoudieh never has been filled up, because it is scoured by the current of the river.

The openings of the canals must be placed in a position where the lesser bed of the river differs as little as possible in extent from the greater bed, or where at least the position of the lesser bed may be maintained in a stable position by means of spurs and dikes; thus the pool above the Ibrahimieh canal is often filled by considerable deposits coming from the banks of sand which the water carries in front of the head of the canal, because in this place the width of the river is too great for the low-water discharges, and because the position also of the current in its bed is not sufficiently fixed naturally or artificially.

The dredging in the canals must be regulated in such a manner, especially during flood at the moment that the water is most charged with material in suspension, that the velocity will not be diminished notably, transforming many pools into settling basins. The regimen of the canals should be organized as much as possible in such a manner that the velocity will always be sufficiently strong to maintain in suspension the fertilizing muddy materials, without being too great to erode the banks.

These canals must be watched to see that they carry only the water strictly necessary for the requirements. If, in order to comply with the conditions of velocity indicated above, it is necessary to give some of them a too great discharge, it must be so arranged that this supplementary water should flow without stoppage and with a normal velocity as far as the reservoirs arranged for this purpose, or in a sufficient quantity as far as the drainage canals.

The fulfilling of these conditions constituted without doubt a complicated and difficult problem to solve. But it is certain that they have not taken sufficient account of all these requirements, of which experience has well indicated the utility, for the fellah is obliged to move each year a considerable quantity of earth to assure irrigation of his fields. It is very probable that the maintenance of the canals will always continue to require each year enormous earth-work, because the reduced velocity of the water necessarily causes the deposit of a portion of the material which it holds in suspension, but they will surely obtain amounts less than those which now exist by a serious study of the works of irrigation and by the establishment of a judicious regimen for the distribution of water.

Up to late years Egypt had for the execution and maintenance of works a powerful instrument in the *corvée*, and it was used without stint; but, thanks to the progress of modern ideas, this instrument is to-day much ameliorated, and it can no longer render the service which was formerly exacted of it. Thus the Government finds itself obliged to rely on its financial resources for the funds necessary to assure the execution for a great part of these works of maintenance, only reserving for the *corvée* the least onerous earth-work. Under these conditions engineers find themselves naturally obliged, much more than in the past, to examine the means of reducing as much as possible the expense of maintenance and to occupy themselves with this important question, which they had largely neglected when labor cost them nothing.

The drainage of irrigated lands is an essential condition of maintaining their fertility, and in most countries where irrigation has been practiced for a long time the works intended for carrying off the waters of drainage are as important as the works constructed for obtaining irrigation water. Egypt is much behind in this respect; nevertheless the permeability to a great depth of the soil, the small slope of the surface, the disastrous effects of saline deposits, which subsoil infiltration produces, require that she should arrange in a very special manner and with the greatest care for the hurtful water. They were very often content, even quite recently, to bring the water to the lands and to increase the humidity of the soil without establishing at the same time the indispensable net-work of drainage ditches along the canals, as well as around the irrigated lands. It has resulted that considerable areas are gradually lost, and can only be reclaimed for cultivation after they have been provided with drains and when repeated washings of the soil shall have

gotten rid of the salt which rendered them sterile. It has been seen elsewhere that the problem of draining the lands is a delicate one to solve in the low portions of the Delta, on account of the varying levels of the lakes which border the sea.

Notable improvements have been introduced since a few years in the service of irrigation as it affects the regulation of the bed of the canals, the better utilization and more careful maintenance of the works now existing, the construction of new distribution works, and the regulation of the flow of the water, especially in the time of the flood; but there yet remains much to be done in this respect. In addition, the distribution of water in a manner to regulate as much as possible its employment is to be organized. This will be a complete revolution in the system of Egyptian irrigation, because on the one hand the peasant is in the habit of drawing largely from the canals according to his needs and beyond his needs, and on the other hand usage and custom differ in one region and another when the decision of the agents of the Government is now the only rule which governs the distribution of the water among those interested. There exists many agricultural councils and provincial councils, who should, according to the law, especially occupy themselves with these questions, but this law has remained a dead letter. Besides, it is necessary to remark, it is not very long since property rights have been regularly instituted in Egypt, and the country is not sufficiently trained and has not sufficiently understood the proper interests to allow with security the groups of proprietors and syndicates to direct any system of irrigation canals without the supervision of the Government. The Government must for a long time centralize in its hands every service of irrigation. It may avoid always without doubt many mistakes and errors by giving regularly and legally to the representatives of the people the right to express their opinion on the questions of irrigation which interest them.

In the present state of Egypt, the principal results which are intended to be obtained from the execution of new works are as follows:

First. The improvement of the irrigation region by rendering the discharge of the canals during low water as independent as possible of the level of low water, by diminishing the expense of maintenance, by raising the level of the water in order to bring it to the surface of the soil, by regulating the drainage of the surplus water of irrigation.

Second. The substitution of the method of irrigation for the system of basins of inundation in the districts where basins still exist.

Third. By regulating the discharge of the Nile so as to decrease the too high floods and increase the extreme low water.

The last international conventions, which followed the conference which was held in London in 1884, have allowed Egypt, involved in debt, to commence the realization of the first part of this programme. In the loan of £9,000,000, which had just been consented to by the powers, there has been reserved £1,000,000 to be used for the amelioration of the irrigation system. The works allotted to this loan are now in course of execution under the direction of Col. Scott Moncrieff, under secretary of state to the ministry of public works, assisted by English engineers who have acquired in India experience in this kind of work. These works, commenced in 1886, are not sufficiently advanced to yet estimate their results, even partially, but their plan is now sufficiently determined to be able to indicate the grand lines. They are exclusively distributed in Lower Egypt, in Fayoum, and in the part of Upper Egypt watered by the Ibrahimieh canal.

Lower Egypt.—The works projected in Lower Egypt comprise especially the strengthening of the great dam at the point of the Delta, and the distribution of the water between the two branches of the Nile, and outside the branches by three grand canals taking their water from the pool above this dam. The present foundation of the dam, which is at the 8.20-meter level above the sea, having been damaged in many points in consequence of settling, it is proposed to strengthen it by masses of masonry to the maximum of 9.50 meters in the worst part and 9 meters in the better parts, and to enlarge the dam throughout its whole length. The fermeture of the arches will be obtained by means of iron gates, which permit the water to be raised to an altitude of 14 meters above the lowest water. It appears quite venturesome to make the whole irrigation of Lower Egypt depend upon a work founded at such a little depth upon a subsoil so compressible.

The provinces between the two branches of the Nile will be solely supplied by the Rayah Menoufieh, which, with its width of 50 to 55 meters, suffices for the daily discharge, almost without

modification, of the 14,000,000 to 16,000,000 cubic meters necessary at low water. It will be necessary, however, to enlarge the inlet work somewhat, to the detriment of the lock which is placed there.

For the provinces of Galoubieh, Dakalieh, and Charkieh, situated to the east of the Damietta arm, and whose irrigation in summer requires the daily discharge of about 11,000,000 cubic meters, a part of this quantity (about 2,300,000 cubic meters) will be furnished by the canals of Ismailieh, Charkieh, and Bessoussieh. The remaining 8,500,000 cubic meters will be provided by the new canal being constructed, called Rayah Charkieh. This canal will have its inlet just above the dam of the Damietta arm. It is planned with a width at bottom of 26 meters and an altitude at its mouth of 9.50 meters. Its slope is 8 centimeters per kilometer; the side slopes are 1 base to 1 vertical; the depth below the level of the soil varies from 6 to 8 meters, and the difference in height between the bottom and the top of the embankments is fixed at 9 meters, with a berme 6 meters wide half-way up.

This canal, which is 638 kilometers long, will be prolonged at its extremity by the Sahel canal, then by the Mansourieh canal, and finally by the Charkaouieh of Damietta, parallel to the Damietta branch, as far as the sea-shore.

Finally, on the left bank of the Rosetta branch, the province of Behera will be watered solely by the Rayah Behera, which now exists, and which will be arranged from its origin with a width of 16 meters at the bottom and a slope of 75 millimeters per kilometer. The elevating-machines of the Katatbeh and the Mahmoudieh will be done away with, and the two canals fed by these machines will receive their water from the Rayah Behera alone.

In consequence of the execution of these works the greater portion of the low water will be stopped at the dam of the Delta, to be employed for irrigation. Navigation will then become impossible in the two arms of the river below this dam. Always below Mansourieh, on the Damietta branch, and a little farther than Kafr-Zaiah, on the Rosetta branch, the depth of the water is such that navigation is always impossible here during low water. They have managed to avoid this stopping of navigation in the upper portion of the branches of the Nile in the following manner:

The regulation works of the Charkieh and its prolongations, as far as Mansourieh, will be furnished with locks for navigation. They will thus have created a vast navigable canal along the Damietta branch as far as Mansourieh, where locks will be established between the Nile and the canal, and will permit boats to resume their route on the river, always practicable below this point. Another navigable way will be created between the branches of the Nile by means of the Rayah Menoufieh and its prolongation, the Bagourieh canal, as far as Goddaba, a point situated a little north of Kafr-Zaiah, on the Rosetta branch. By placing a lock connected with the Nile at this point boats coming from the dam will be able to continue their voyage by the river and also return, either from Rosetta by the river or by the Mahmoudieh canal from Alexandria.

The two parts of the Nile rendered impracticable for navigation will be thus replaced by a series of navigable canals following each of these two branches. These principal lines of navigation will be connected with the secondary lines which already exist.

Such is the general plan of the works which are in process of construction in Lower Egypt. A few important lines of drainage will be also established in the lower portion.

Fayoum.—The works projected for Fayoum are generally works of detail. They consist of the arrangement of inlets designed to insure an excellent distribution of water among the different parts of the province, and in the substitution at some points of irrigation canals for the basin system which still exists here.

Upper Egypt.—The principal works which will be executed in Upper Egypt are designed to feed with water charged with sediment certain basins which now receive only settled water coming from the upper basins, and which are separated from the Nile by the strip of land irrigated by the Ibrahimieh canal.

These works consist principally of building syphons, constructed under the Ibrahimieh canal, which can play a double rôle:

To supply by means of transverse canals, during low water, the basins to the right of those which have been established, with sedimentary water;

To serve at the same time to empty into the Nile during low water the drainage of the irrigation water from the irrigated lands situated between the Ibrahimieh and the longitudinal dikes of the basins, lands that have become impregnated with salt, because they have never been arranged with any provision for drainage.

According to present intentions this vast amount of work will be finished in two years. If it is executed under good conditions it will accomplish a great advance in the actual condition of irrigation in Egypt.

The financial resources of the country are too limited to allow the second part of the programme of amelioration, which has been indicated above, to be touched; that is to say, the extension of the system of irrigation in the region of basins.

As to the third part of the programme (that is to say, the regulation of the course of the Nile with the object of diminishing the discharge of the floods and increasing the discharge of low water), its realization is still distant. Nevertheless, an interesting project has been started for this purpose in late years, and has already been subjected to the first summary investigation. M. Jacquet, inspecteur général des ponts et chaussées, came, in fact, to Egypt a few years ago to examine it, and from the data which he collected at that time he reported on the practicability of its execution in his report dated July 15, 1882.

This project* was presented by M. de la Motte, and was backed by a company which was formed in Paris under the name of "The Society for Studying the Nile." It consists of the creation of an enormous reservoir in the valley of the Nile above the defile of Gebel Cilcila, or a few kilometers to the north of Assouan. The place, in fact, appears perfectly adapted for this. At Gebel Cilcila the Nile flows over a bed of rock in a defile 400 meters wide, which M. Jacquet proposes to dam by a masonry wall able to support the pressure of 20 meters of water. A new bed, 300 meters wide, closed by a movable dam, and a lateral reservoir 700 meters wide, both cut out of the rock, on the right bank of the river, will serve to carry off the waters of the flood, the great masonry dam being always above water. A derivation with locks for navigation and an irrigation canal having its inlet above the dam in the left bank would complete the work. It would be necessary, also, by a second insubmersible dam of about 1,300 meters in length, to close the depression which exists 2 kilometers to the east of the present one, up the river, in a line of rocks which cross the valley. This depression is formed where an old arm of the river flowed.

With this series of works there will be obtained in the great plain of Kom Ombo, which the Nile crosses above the rock bed of Gebel Cilcila, an enormous reservoir, with a surface of 1,400,000,000 square meters, where they will store 7,000,000,000 cubic meters of water, and whence they can deliver to Egypt a continuous flow of 400 cubic meters per second independently of the normal discharge of low water of the river. They will thus have sufficient water to create 400,000 hectares of cultivable lands which do not exist to-day.

This is a grandiose conception. It will require to execute it an expenditure of 100,000,000 francs at the maximum, according to the calculations of M. Jacquet.

When will Egypt become sufficiently prosperous to be able to turn her thoughts to such works?

* See Plate XXII.

MINISTÈRE DE L'AGRICULTURE.

BULLETIN.

DIRECTION DE L'HYDRAULIQUE AGRICOLE.

L'IRRIGATION EN ÉGYPTÉ.

PAR J. BAROIS,

Ingénieur en chef des Ponts et Chaussées, Secrétaire général du Ministère des Travaux publics en Égypte.

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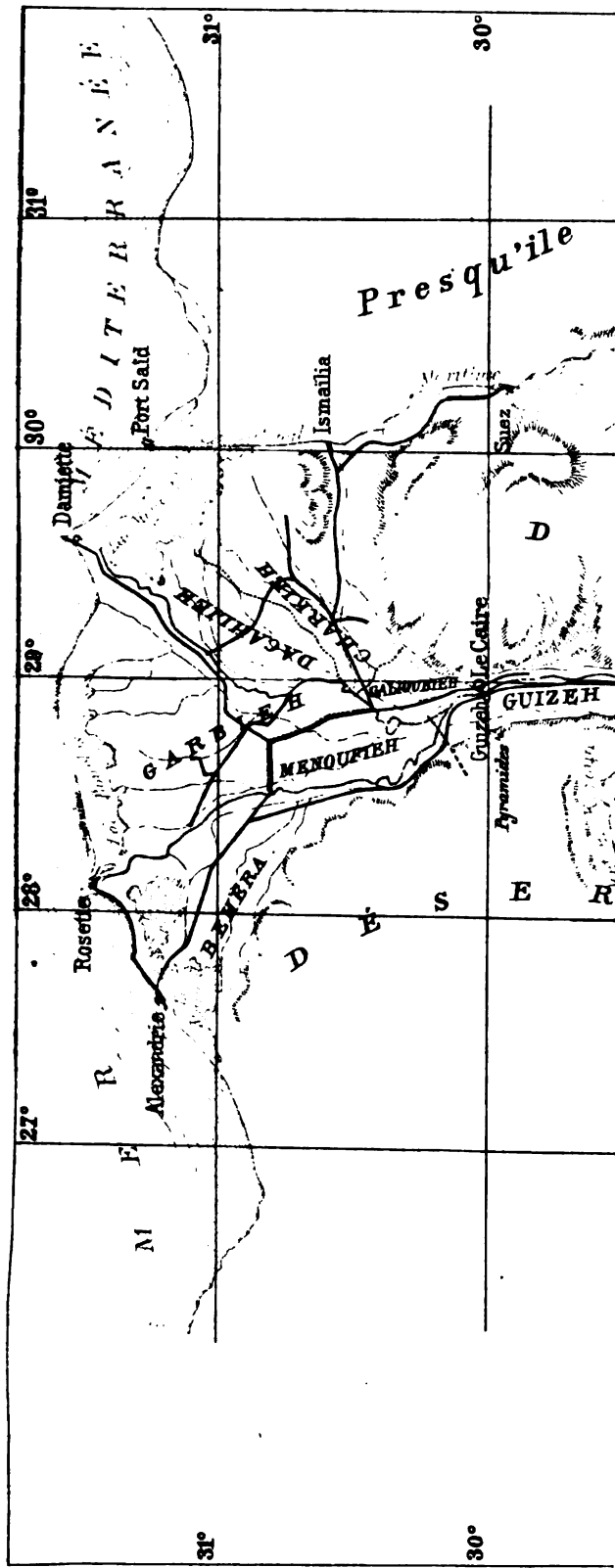
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Hydraulique agricole

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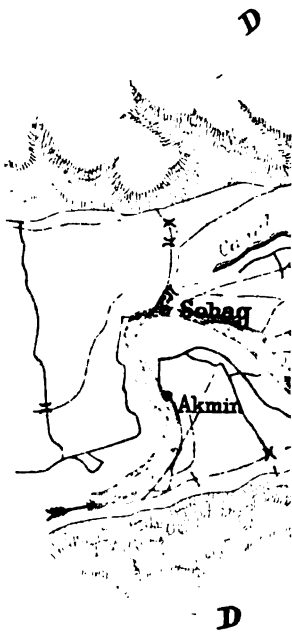


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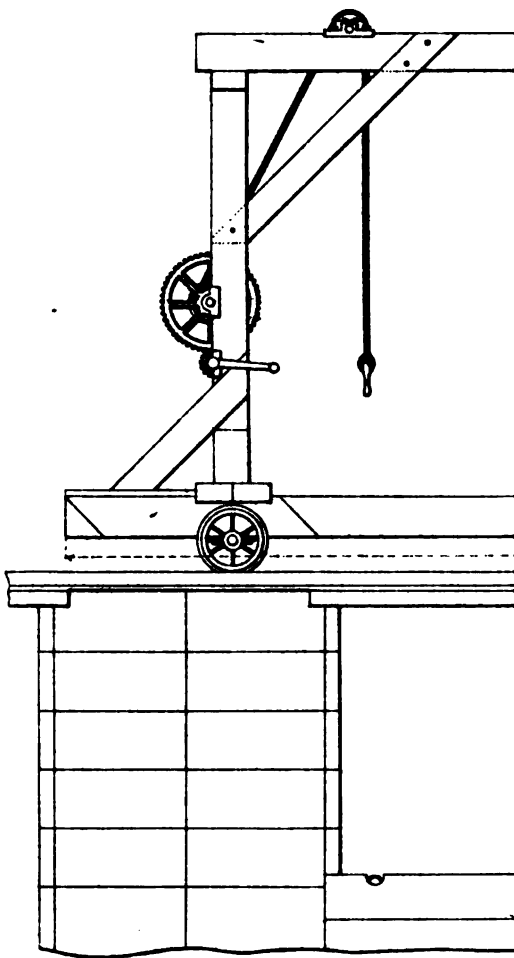
- - - - Canaux, Cours d'eau
 ——— Diques.
 x Ouvrages de retenue



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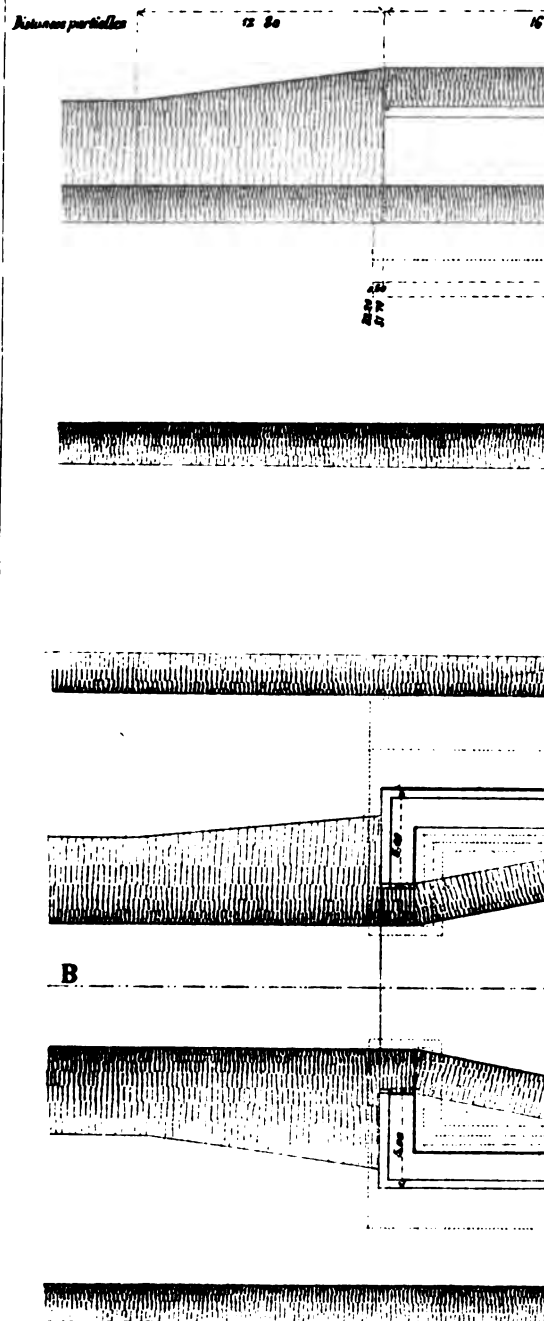
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Elévat



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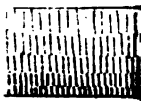
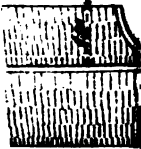
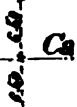
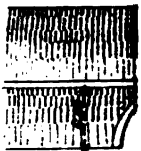
Hydraulique agricole

COUPE DE QUAIS
sur le bord du Nil.

Fig. 1

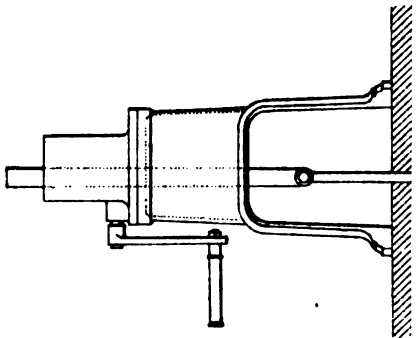
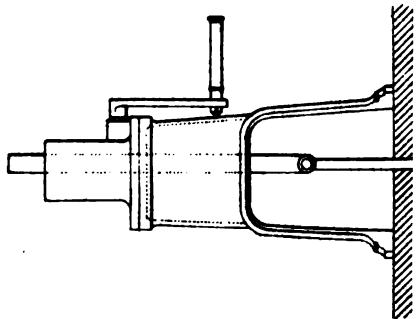
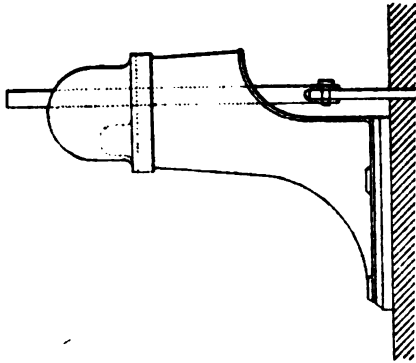
Coupe des quais circulaires du grand barrage

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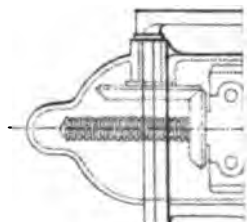
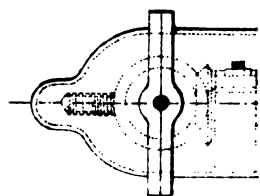
Hydraul

ÉCLUSES DE CHOUBRAH, SIRIAKOS ET BELBEIS.
Doubles vannes des Ponts-Barrages.



ECLUSES DE CHOUBRAH, SIRIAKOS, BELBEIS

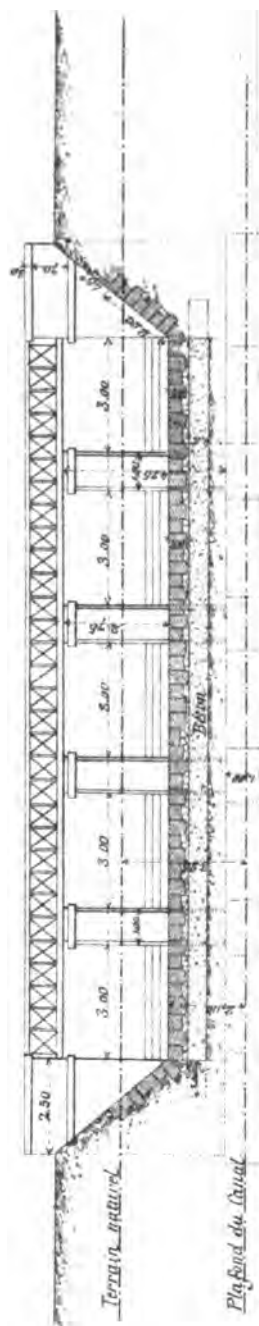
Vannes du service des conduits latéraux .

Echelle de 0^m005 p^rl^m

DÉVERSOIR DE NEFICHE.

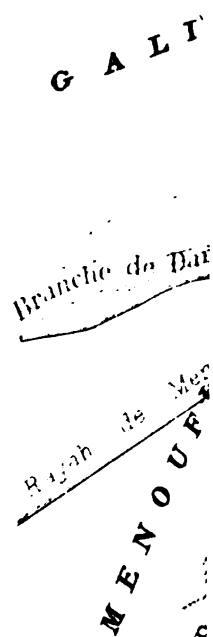
Echelle de 0^m005 par mètre

Elévation de la tête amont



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Fig. 1. EMPLACEMENT DU GRAND BARRAGE
de la Pointe du Delta.

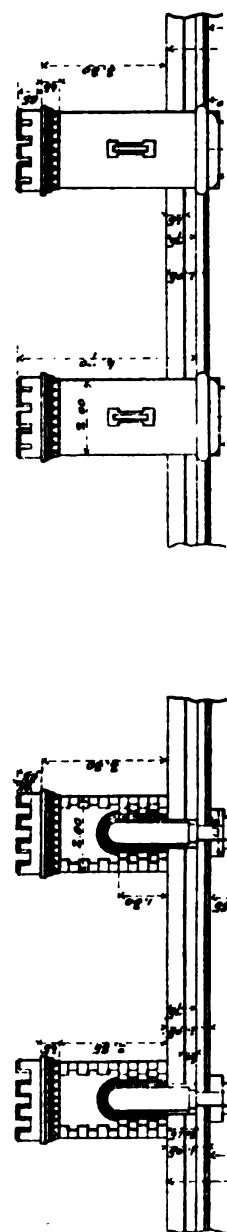


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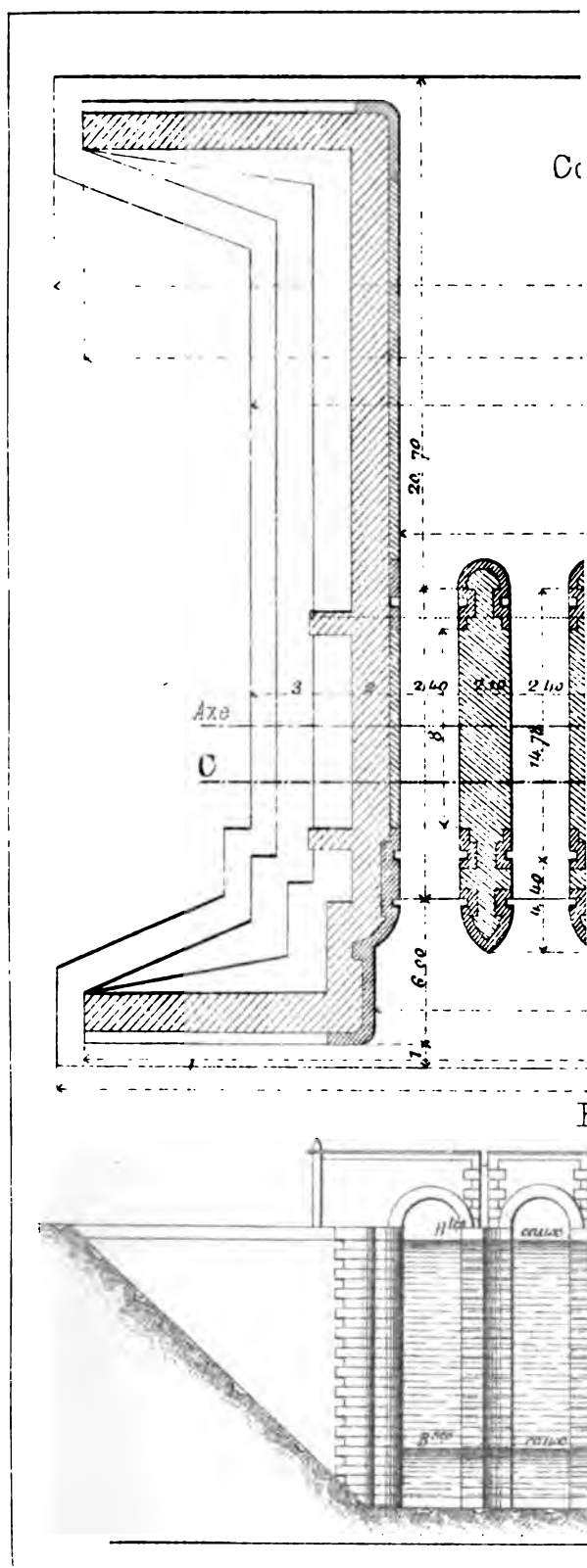
GRAND BARRAGE DE LA POINTE DU DELTA.

Détails d'une Arche.

Amont. *Echelle de 0^m.005 par mètre* Aval.

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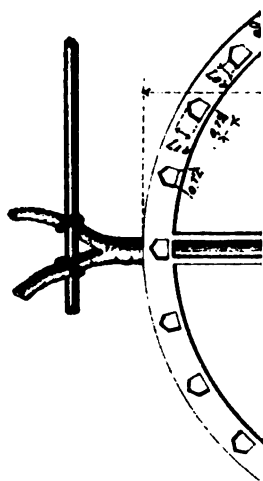
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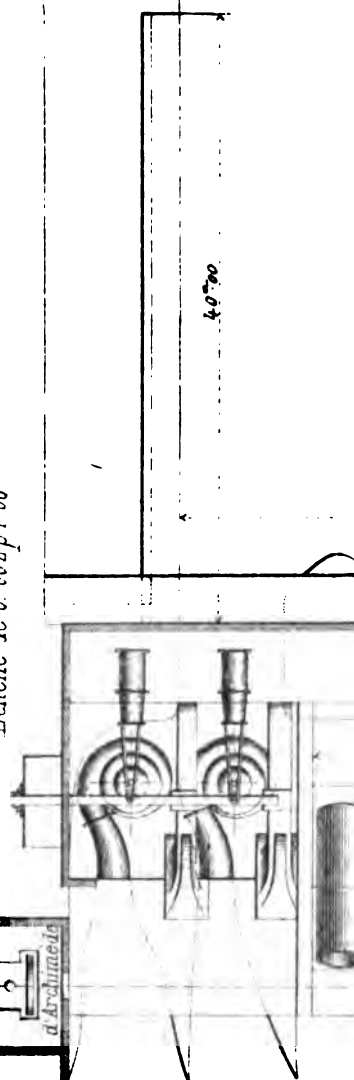
ROUE ELEVATOIRE (*TABOUT*)



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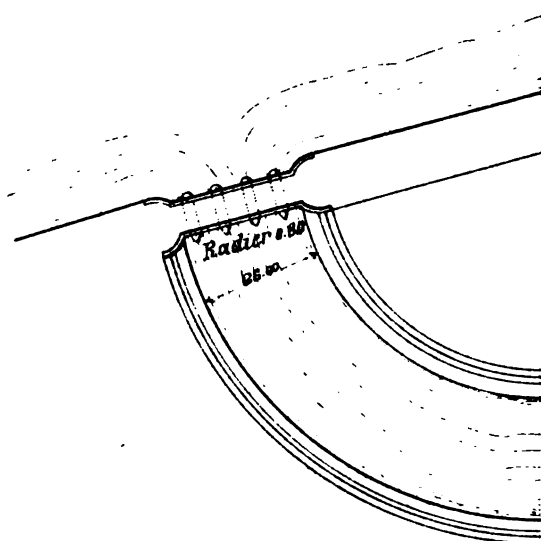
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MACHINES DU KATATBEH

Plan général
Echelle de 0^m002 p 1^m00Machine
pour les vis
d'Archimède
Bâtiment
des
Chaudières.

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L'IRRIGATION EN ÉGYPTÉ.

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FASCICULE H.—PLANCHE XVIII.



MANIÈRE DE TENIR LE NATTAL.

L'IRRIGATION EN ÉGYPTE.

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FASCICULE H.—PLANCHE XIX.



CHADOUF.

L'IRRIGATION EN ÉGYPTÉ.

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FASCICULE H.—PLANCHE XX.



SAKIÉ.

NORIA (SAKIE). Fig. 1.2.3.4.5.

ROUE HYDRAULIQUE A PALETTES Fig. 6.7

Echelle de 0^m02 p^r 1^m00.

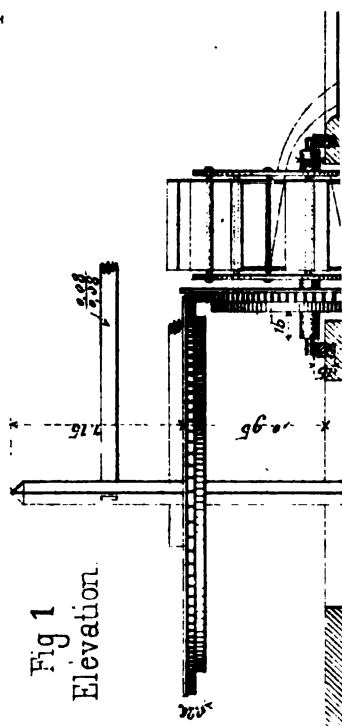
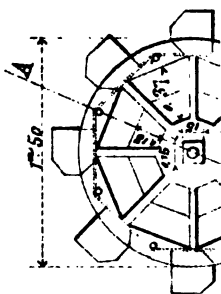
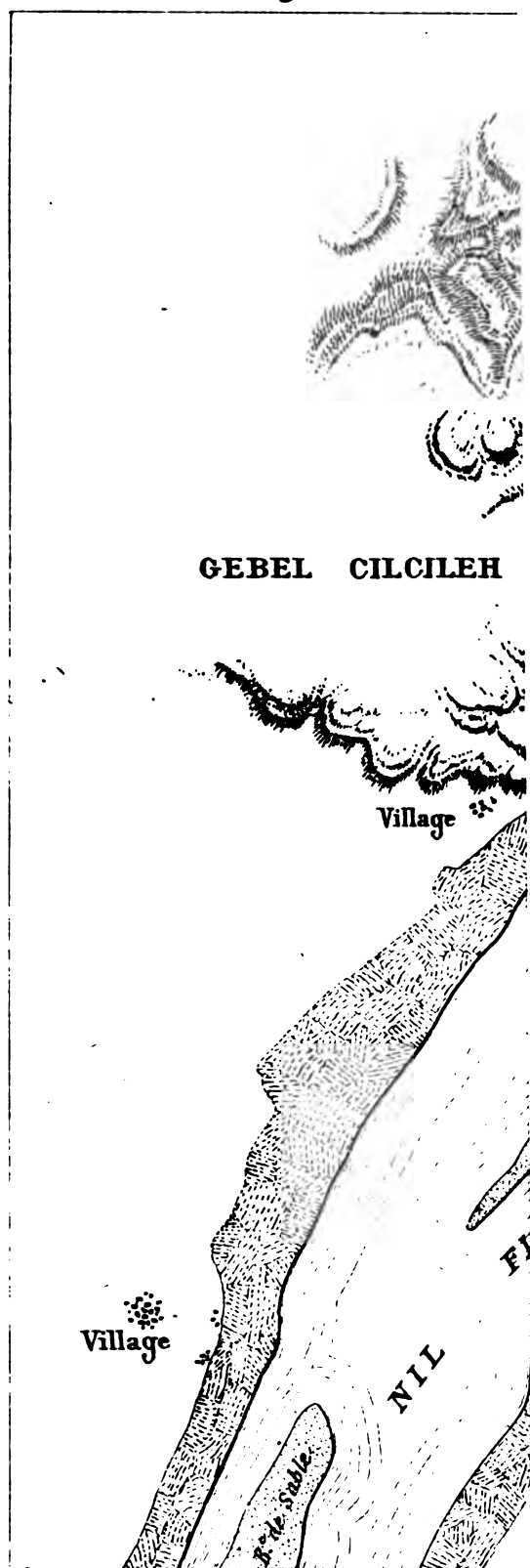


Fig 1
Elevation.

Fig. 2 Elevation laterale
de la noria.



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